AN ENVIRONMENTAL HEAT TRANSFER STUDY
OF
A ROCKET MOTOR STORAGE CONTAINER SYSTEM

Allen Henry Wirzburger

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THESIS

AN ENVIRONMENTAL HEAT TRANSFER STUDY OF A ROCKET MOTOR STORAGE CONTAINER SYSTEM

by

Allen Henry Wirzburger

Thesis Advisor: T. E. Cooper

December 1972

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An Environmental Heat Transfer Study
of
A Rocket Motor Storage Container System

by

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Lieutenant, United States Navy
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ABSTRACT

The heat transfer characteristics of a rocket motor storage container system have been investigated using analytical and experimental techniques. Analytically, both closed form and numerical solutions have been developed. These solutions may be used to determine maximum temperatures and temperature gradients within the rocket motor. Comparison between theoretical and experimental values of temperature are within the estimated experimental uncertainties of ± 3°F. It is proposed that the theoretical solutions can be used to thermally optimize container design.

A secondary investigation was carried out to determine the feasibility of using cholesteric liquid crystals, a temperature sensitive material, to thermally map the surface of the container. The crystals appear to remain stable under desert type conditions and produce brilliantly colored displays of the temperature field.

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TABLE OF SYMBOLS

a = $\sqrt{\frac{\omega r_o^2}{\alpha}}$ = conduction parameter

A_n = area of surface n $\frac{\text{sq in}}{\text{in}}$

B = $\frac{1}{T}$ = volume coefficient of expansion $\frac{1}{°R}$

c = specific heat $\frac{\text{BTU}}{\text{lbm °F}}$

D_n = $D_n' + D_n''$ = length of minimum length line, n in.

D_n' = length of tangential segment of minimum length line, n in.

D_n'' = length of radial segment of minimum length line, n in.

E = $\frac{\varepsilon}{1-\varepsilon}$ = emissivity parameter

F_{m-n} = view factor, fraction of isotropic radiation from A_m intercepted directly by A_n

$\mathcal{F}_{m-n}$ = radiation exchange factor, fraction of radiation passing from A_m to A_n directly and indirectly

g = acceleration of gravity $\frac{\text{ft}}{\text{sec}^2}$

h_{CON} = convection heat transfer coefficient $\frac{\text{BTU}}{\text{hr-ft}^2\text{°F}}$

h_{RAD} = radiation heat transfer coefficient $\frac{\text{BTU}}{\text{hr-ft}^2\text{°F}}$

$\bar{h}$ = $h_{CON} + h_{RAD}$ = effective heat transfer coefficient $\frac{\text{BTU}}{\text{hr-ft}^2\text{°F}}$

i = $\sqrt{-1}$

J_n = radiosity of node n $\frac{\text{BTU}}{\text{hr-ft}^2}$

k = thermal conductivity $\frac{\text{BTU}}{\text{hr ft °F}}$

k_c = effective thermal conductivity $\frac{BTU}{hr\ ft^\circ F}$

r_n = radial distance from center of rocket motor to point n in

r_o = inner radius of rocket motor in

S_n = length of surface n in

t = time min

T = temperature of position r at time t °R

T_∞ = storage container temperature °R

T_M = maximum temperature of storage container °R

T_A = average temperature of storage container °R

Z = $\sqrt{\frac{i\omega r_o^2}{\alpha}}\ \xi$ = dimensionless distance parameter

α = thermal diffusivity $\frac{ft^2}{hr}$

β = $\frac{\bar{h} r_o}{k}$ = Biot modulus

δ = width of air gap in

ε = emissivity

ξ = $\frac{r}{r_o}$ = dimensionless distance

θ = $\frac{T - T_A}{T_M - T_A}$ = dimensionless temperature

θ^* = dimensionless temperature for supplementary problem

θ_a = construction angle for crossed-strings method radians

θ_r = relative amplitude of maximum temperature at point of interest to the maximum temperature of the storage container

μ = dynamic viscosity $\frac{lbm}{ft\text{-}hr}$

ρ = density $\frac{\text{lbm}}{\text{ft}^3}$

σ = Stefan-Boltzman constant 0.171×10^{-8} $\frac{\text{BTU}}{\text{hr ft}^2\,{}^\circ\text{R}^4}$

τ = $\tau(t)$ = solution of ψ ;

= $e^{im\omega t}$ for large values of time

ϕ = $\phi(r)$ = solution of ψ

ψ = complex temperature = $\theta^*(r,t) + i\theta(r,t)$

ω = frequency of sinusoidal variation $\frac{2\pi}{24 \text{ hours}}$

ω_T = resulting uncertainty in calculated temperature °R

ω_C = uncertainty in calculated temperature due to variation in volumetric heat capacity °R

ω_K = uncertainty in calculated temperature due to variation in conductivity °R

ω_ε = uncertainty in calculated temperature due to variation in emissivity °R

$$Gr = \frac{\rho^2 g B (\Delta T)\delta^3}{\mu^2} = \text{Grashof Number}$$

$$Pr = \frac{c\mu}{k} = \text{Prandtl Number}$$

Bessel Functions

I_o , J_o , K_o , BER , BEi

$$X_R = BER_o(a) + \frac{a}{\sqrt{2}\beta} BER_1(a) + \frac{a}{\sqrt{2}\beta} BEi_1(a)$$

$$X_i = BEi_o(a) + \frac{a}{\sqrt{2}\beta} BEi_1(a) - \frac{a}{\sqrt{2}\beta} BER_1(a)$$

$$\delta^* = \tan^{-1} \frac{BEi_o(a\xi)X_R - BER_o(a\xi)X_i}{BER_o(a\xi)X_R + BEi_o(a\xi)X_i} = \text{time delay} \quad \text{radians}$$

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I. INTRODUCTION

The purpose of this investigation was to develop a heat transfer model that will allow prediction of the temperature distribution in a container stored rocket motor placed in a hostile thermal environment such as the desert. It is proposed that such a model would be a useful tool for thermally optimizing future container designs. As extreme variations in the rocket motor temperature may lead to large thermal stresses in the propellant which could result in fracture, or otherwise degrade the performance of the motor, a major objective of this study was to design a model that could reliably predict the thermal gradient in the motor. The predictions would be based on the surface temperature distribution, the thermal properties and the geometrical details of the system. The model may also be used to predict a critical temperature range over which the propellant must be chemically stable when in a storage situation. The upper limit of this temperature range is referred to as the design temperature of the system. As the design temperature for most weapon development projects is derived from dump storage conditions, a dump storage situation was used to obtain the experimental data for this project.

Several approaches were taken to predict the rocket motor temperature distribution from a knowledge of only the surface temperature distribution of the storage container and the thermal properties and geometrical details of the

experimental model. The experimental model used in this test was a once-fired Navy antisubmarine rocket (ASROC) motor, filled with dry desert blow sand to simulate the propellant, and placed in its storage container. This container system was placed in a dump storage site at the Naval Weapons Center, China Lake, California to simulate a desert environment.

The method of complex temperatures [Ref. 1] was used to develop an analytical prediction of the transient temperature field that exists in a container stored rocket motor. The analytical model assumes that heat is transferred only in the radial direction and that the container surface temperature variation is sinusoidal with time. Comparison between theory and experiment is within experimental uncertainty when temperature is interpreted as "bulk" temperature. The analytical model is especially useful for studying geometrical and thermal physical property effects on rocket motor temperature. Such parameter studies have been carried out and the results are presented in a form that will be useful from a container design point of view.

TRUMP [Refs. 2 and 3], a computer program for transient and steady-state temperature distributions in multidimensional systems, was used to obtain detailed information about the thermal state of the rocket motor. TRUMP allows actual container surface temperature distributions to be used as well as sinusoidal variations. In addition, both one dimensional (radial) and two dimensional (radial and circumferential)

heat transfer were modeled with TRUMP, using both the sinusoidal and actual temperature distributions. The actual temperature distributions were obtained from the experimental data of the motor container system.

Comparisons between the experimental values and those predicted by the models were in good agreement,with those predicted by TRUMP using the actual temperature distribution as the boundary condition being the closest. However, the sinusoidal variations used in both the analytical model and the TRUMP model are also suitable for design purposes.

Another aspect of this project was to obtain the storage container surface temperature distribution using cholesteric liquid crystals, a material that undergoes brilliant changes in color over known, well defined temperature ranges. Color slides and movies were taken of the liquid crystals demonstrating the feasibility of using them for on site temperature measurements.

II. BACKGROUND

In 1959 the Naval Weapons Center, China Lake recognized the need for a concerted attack on the problem of thermal criteria assignment for new weapon systems. In 1963 a task force was established to study the complete environmental criteria determination problem. The key to this problem seemed to be the thermal area in the storage and transportation events of any item. It was realized that transportation was a short term situation compared to the storage situation. Therefore, the major portion of the life of an item must be in storage. There are three types of storage; covered, igloo and dump. The dump storage situation leads to the more extreme thermal exposure situations which then leads to the design temperature.

As data was not available for the dump storage situation, instrumented storage dumps were created at representative places on a worldwide basis so that statistical data could be derived on a variety of ordnance. The first site was at China Lake, California, in the middle of the Mojave Desert. This site now has the capability to return about 250 channels of information on a continuous time-temperature basis (Figure 1). Other arctic and tropical sites were set up to study extreme conditions.

The dump storage situation was reproduced to study the extreme situation. The ordnance was exposed singly, directly situated on the ground, with the long axis aligned in the

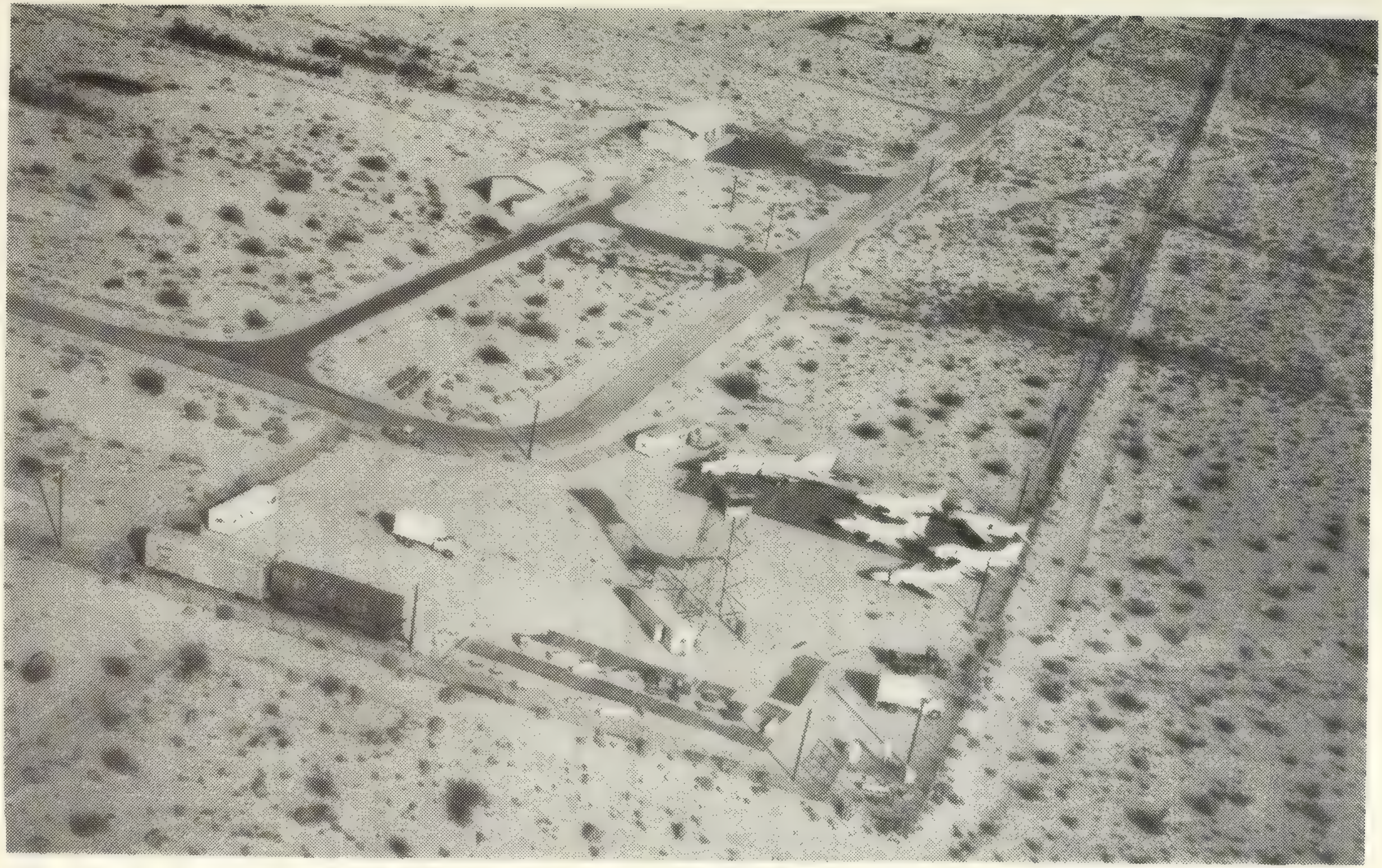

Figure 1. Simulated Storage Site at China Lake.

north-south direction to allow maximum normal exposure of the container surface to the sun's rays. In actual practice, ordnance is usually stacked and oriented in other than a north-south direction, thereby avoiding the extreme situation. Ordnance sitting on the ground receives reflected radiation from the ground, cannot quickly give off heat by conduction to the soil, and is not as apt to be cooled by the prevailing breeze; therefore, extreme temperatures result.

The most important source of heat to the ordnance is the direct radiation from the sun, with reflected radiation of secondary importance. For extreme conditions to occur the wind must be calm (less than 5 knots), the sky clear, and the outside air temperature high. After sunrise, the ordnance skin temperature rises much more rapidly than the ambient air temperature; therefore, the surrounding air cools the ordnance, rather than heats it.

The rocket motors used for the tests were military surplus. Even though the material had served its intended in-Fleet purpose, it was still representative of new hardware, when viewed in a thermodynamic context. When inert rocket motors were available, they were used intact; however, in most cases, once-fired hardware was used. Thoroughly dried desert blown sand, being similar in thermal properties to most propellants, was used to backfill empty rocket motors. It was assumed that the thermal response of the sand filled motors was essentially the same as actual propellant filled motors.

III. EXPERIMENTAL PROCEDURE

Although Naval Weapons Center, China Lake had accumulated vast amounts of data in the past, it was decided to instrument a rocket motor storage container system especially for this project. This would allow base data to be taken exactly where it was required. It also allowed variations in the system without interfering with one of China Lake's ongoing projects. An ASROC system was chosen for this study. The outer storage container was 75 inches long with an inner diameter of 18 inches and a wall thickness of 1/16 inch. The rocket motor was 57 inches long with an outside diameter of 12 inches and a wall thickness of 1/4 inch. Both the container and motor were made of steel.

The rocket motor storage container system was instrumented with 20 gage copper-constantan insulated thermocouple wire which has an ISA Calibration of ± 1-1/2°F over the range -75 to +200°F. Twenty-one thermocouples were originally placed on the system with positions indicated in Figures 2 and 3. The ambient air temperature was measured with thermocouple number 19 which was located in a Stevenson shelter about 60 feet away from the system (Figure 4). The thermocouples were mounted intrinsically on the motor and storage container. Two small holes were drilled approximately 1/8 inch apart in the metal and the individual wires were inserted in the holes. The metal was then hammered around the wires until a snug fit was obtained. Bead thermocouples were mounted at the

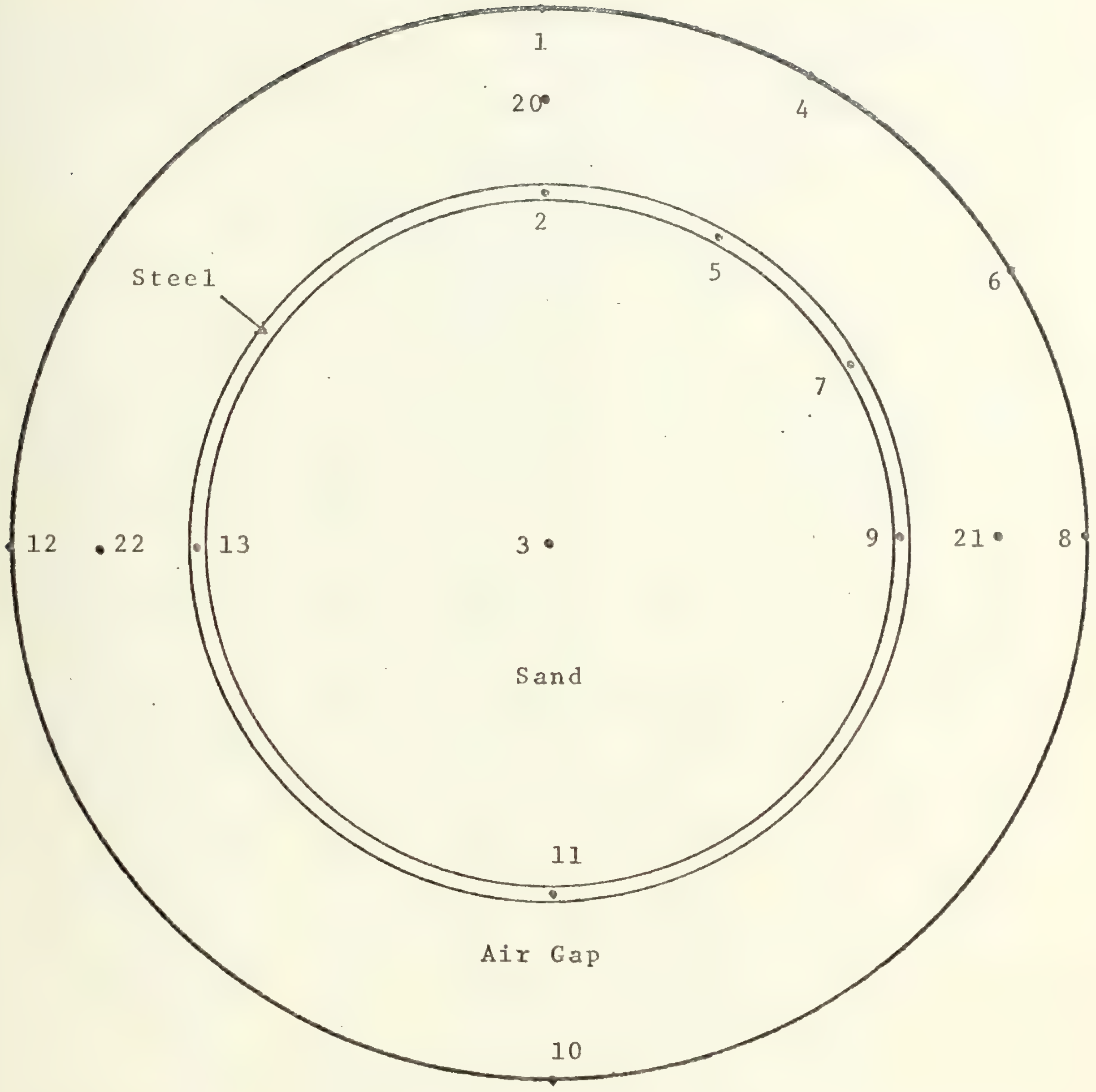

Figure 2. Thermocouple Locations on Experimental System.

Five thermocouples were located under the section painted with the liquid crystals. Their locations corresponding to the ones shown above are: #14= #1, #15= #2, #16= #8, #17= #9, and #18= #3 (See Figure 3).

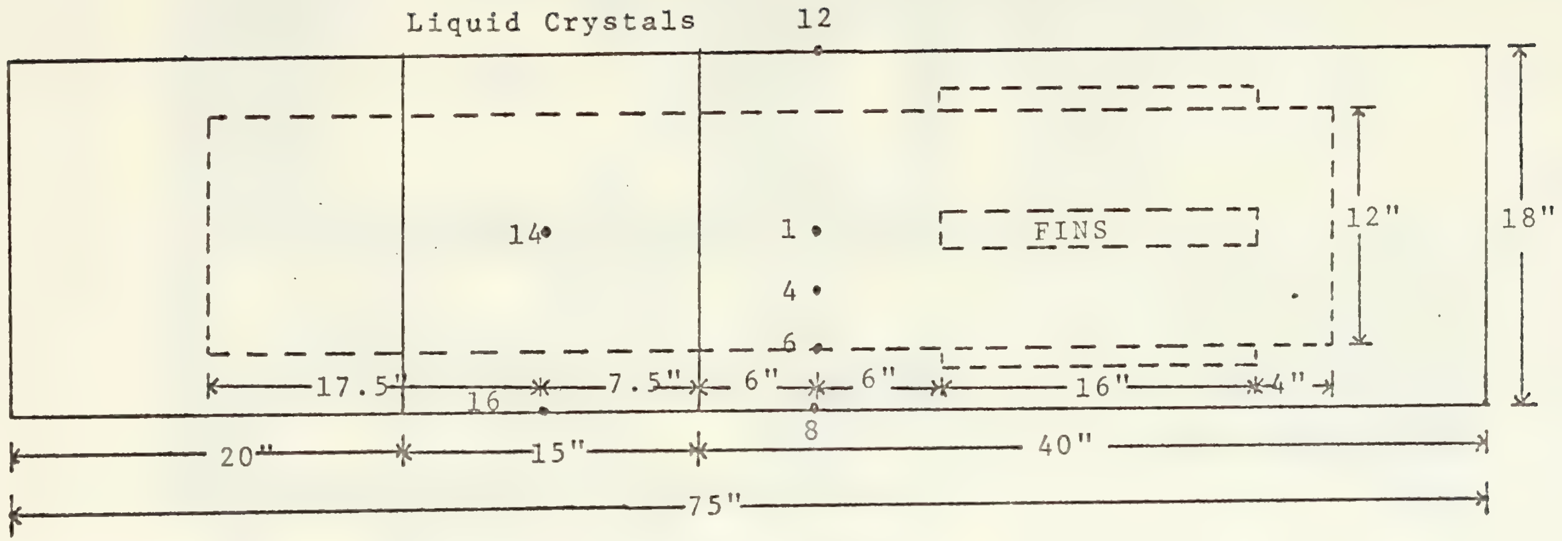

Figure 3. Top View of Rocket Motor Storage Container System.

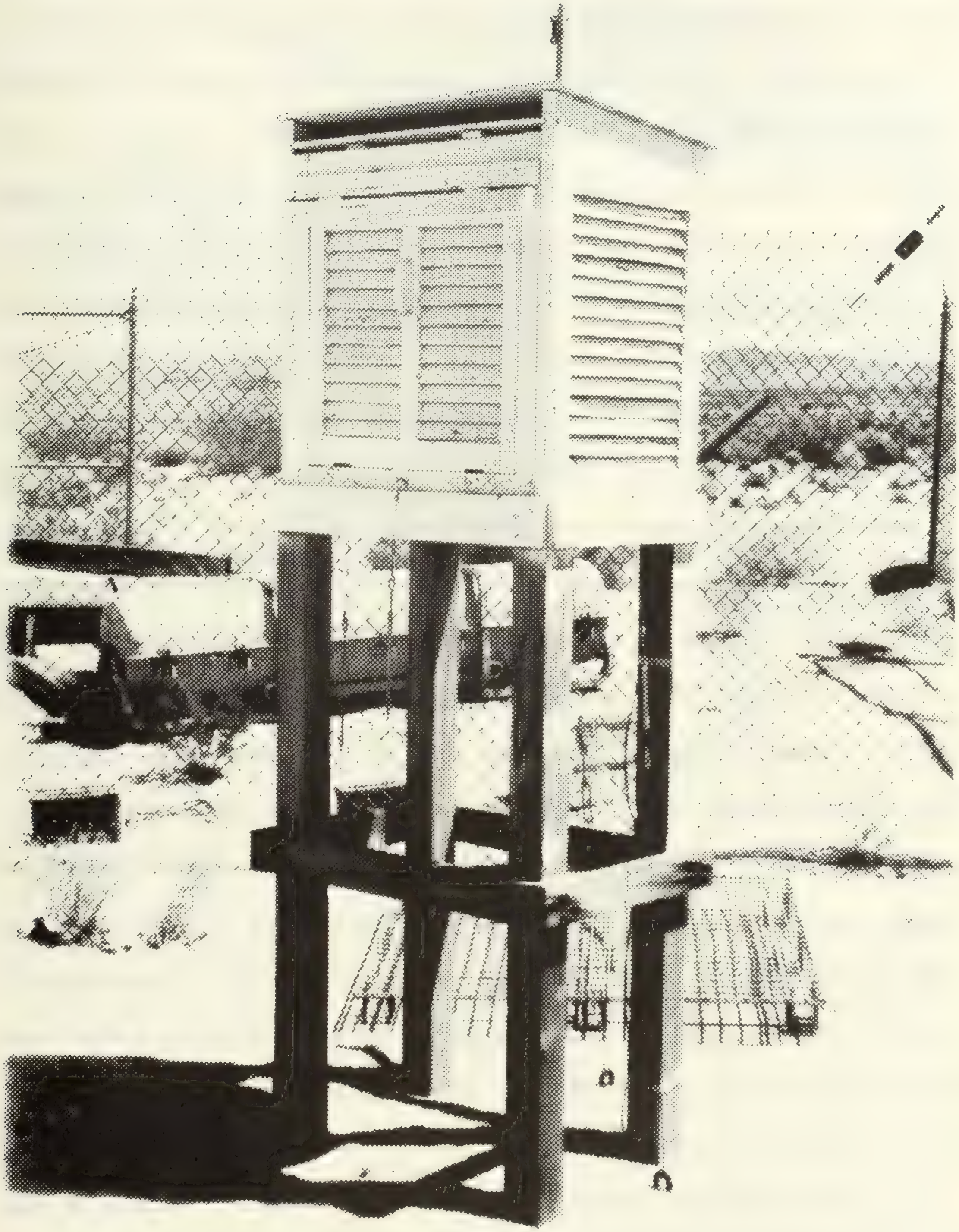

Figure 4. Stevenson Shelter.

center of the motor and in the air gap. The thermocouples located at the center of the motor were supported by small pieces of wood several inches from the bead. The use of these supports was necessary to keep the thermocouples in position when the motor was being filled with sand. After all the thermocouples on the rocket motor were in place, the rocket motor was filled with dry desert blown sand. The wires from the two thermocouples located in the center of the motor were led out a hole in the end cap. To avoid settling of the sand after the motor was in place on the site, with a resulting air gap being formed between the sand and the motor skin, the sand was compacted by striking the sides of the motor with small sledge hammers and then adding additional sand through the hole in the end cap. This was continued until the sand was tightly packed. The hole in the end cap was then sealed. The rocket motor was carefully placed in its storage container (Figure 5) which had previously been instrumented with thermocouples. The thermocouples in the air gap were mounted by affixing the lead wire to the rocket motor at the desired position and then putting a 90 degree bend in the wire so that it placed the bead of the thermocouple approximately 1.5 inches into the air gap. Neither the thermocouples in the center of the motor nor those in the air gap could be considered accurately positioned; however, every effort was made to minimize positioning errors. All thermocouple wires were located inside the storage container and were led through a

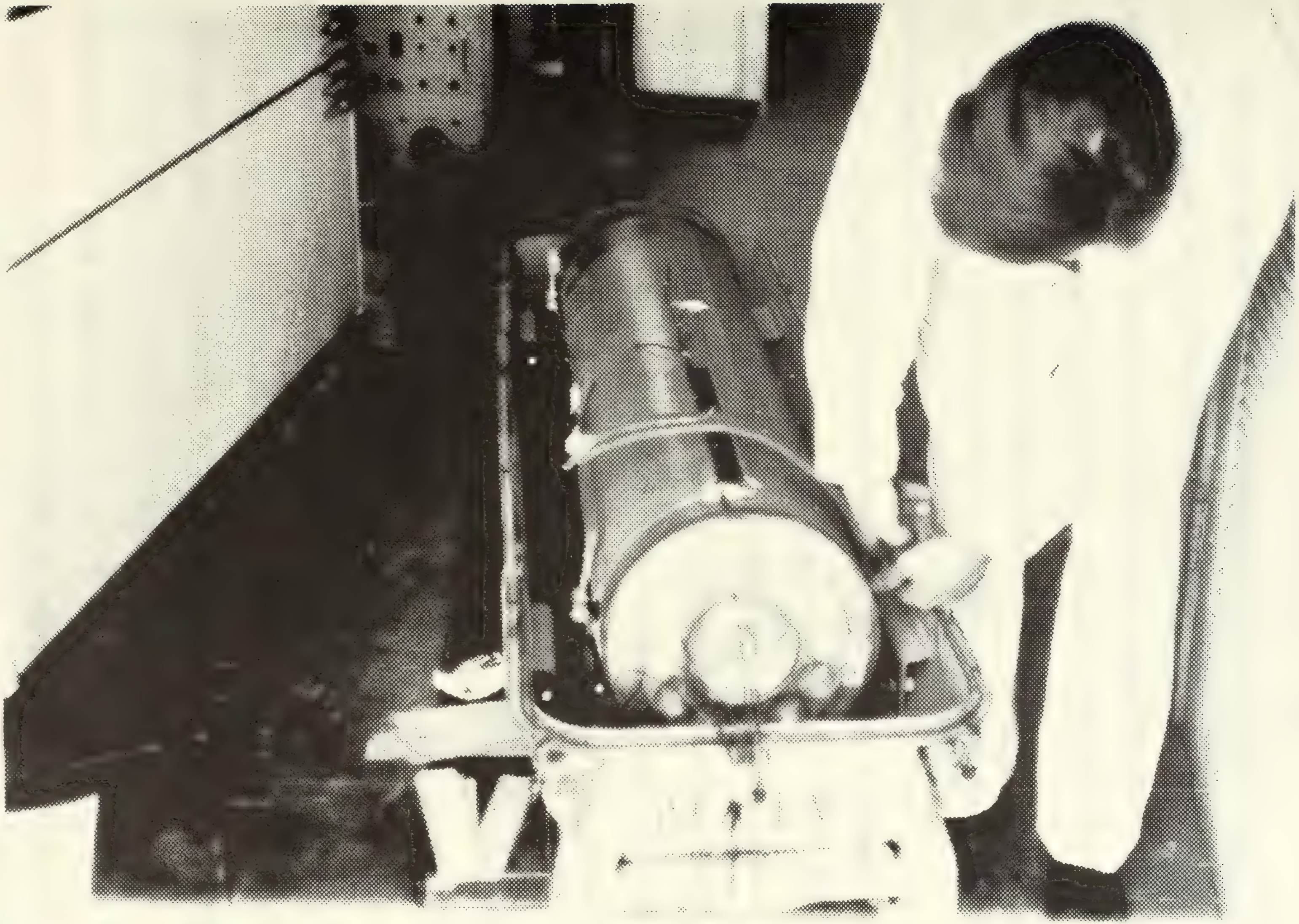

Figure 5. Rocket Motor Mounted in Storage Container.

hole in one end. This hole was then sealed. The two halves of the storage container were then bolted shut.

The outer surface of the rocket motor and the inner and outer surfaces of the storage container were all painted various shades of haze gray. Weathering had caused the painted surfaces to appear fairly rough. This is typical of the conditions of a storage dump. From the condition of the surfaces, it was estimated that the emissivity was approximately 0.9.

Prior to loading the rocket motor into the storage container, it was decided to apply liquid crystals (See Appendix A) to part of the storage container surface in order to obtain a thermal mapping of the surface temperature at any instant of time. Liquid crystals are temperature sensitive materials that produce immediate thermal images in a pattern of colors which respond rapidly to minute changes in substrate surface temperatures. A second reason for applying the crystals to the container surface was to determine the feasibility of using the crystals under adverse environmental conditions (desert atmosphere). Prior to applying the crystals, a 15 inch strip of the storage container, 20 inches from one end, was sprayed with two coats of Testors Spray Pla Enamel No. 1249, Flat Black as a background for the crystals. A one inch strip of 11 different ranges of crystal, with approximately 1/2 inch of black paint between them, was applied over the black paint. Two coats of each crystal were applied, using a small paint brush. The first coat was allowed to dry completely before the second coat

was applied. After the crystals were dry, two coats of Rez polyurethane (gloss clear plastic coating, interior-exterior 77-5) coating were applied by brush completely covering the crystals and black painted area. The polyurethane coating was applied to protect the crystals from wind blown sand and from the ultraviolet rays of the sun. Ten of the eleven crystals had been previously calibrated [Ref. 4]. Using the constant temperature bath procedure recommended in Ref. 4, R-27 was calibrated and the complete calibration results are shown in Table I.

The rocket motor storage container system was then moved to the China Lake dump storage site. The system was aligned in a north-south direction, well away from the influence of other ordnance (Figure 6). The thermocouple leads were connected through a junction box and underground cable to a Honeywell Electronik 25 Recorder which had been calibrated to read the thermocouple output directly in degrees Fahrenheit to an accuracy of ± 1°F. The recorder was located in an air-conditioned building about 60 feet from the system.

Initial data indicated that the number 7 thermocouple was not responding properly and therefore this data was neglected. Initial color photographs were taken of the liquid crystals and it was immediately apparent that good thermal mappings could be obtained if the crystals were stable under the adverse desert environment. The brilliance of the colors exhibited by the crystals under the bright desert sun was much better than had been expected. The

TABLE I
Calibration of Liquid Crystals

NCR Desig.	Color Change	Manufacturer's Responses °C	Calibration Bath 2 Coats Liquid Crystals °C
R-27			
	Red	27.0	25.6±.5
	Green	28.6	28.0±.5
	Blue	30.0	28.7±.5
R-33			
	Red	33.0	32.7±.5
	Green	34.6	33.3±.5
	Blue	36.0	34.2±.5
R-37			
	Red	37.0	36.2±.5
	Green	38.6	37.1±.5
	Blue	40.0	38.0±.5
R-41			
	Red	41.0	40.3±.5
	Green	42.6	41.0±.5
	Blue	44.0	42.0±.5
R-45			
	Red	45.0	42.8±.5
	Green	46.6	43.6±.5
	Blue	48.0	44.3±.5
R-49			
	Red	49.0	46.7±.5
	Green	50.6	47.1±.5
	Blue	52.0	48.4±.5
R-53			
	Red	53.0	50.5±.5
	Green	54.6	52.1±.5
	Blue	56.0	53.3±.5
R-56			
	Red	56.0	53.8±.5
	Green	57.6	56.0±.5
	Blue	59.0	56.5±.5
R-59			
	Red	59.0	56.9±.5
	Green	60.6	57.5±.5
	Blue	62.0	58.9±.5
S-62			
	Red	62.0	60.1±.5
	Green	62.6	60.4±.5
	Blue	63.0	60.9±.5
S-64			
	Red	64.0	60.9±.5
	Green	64.6	61.4±.5
	Blue	65.0	62.7±.5

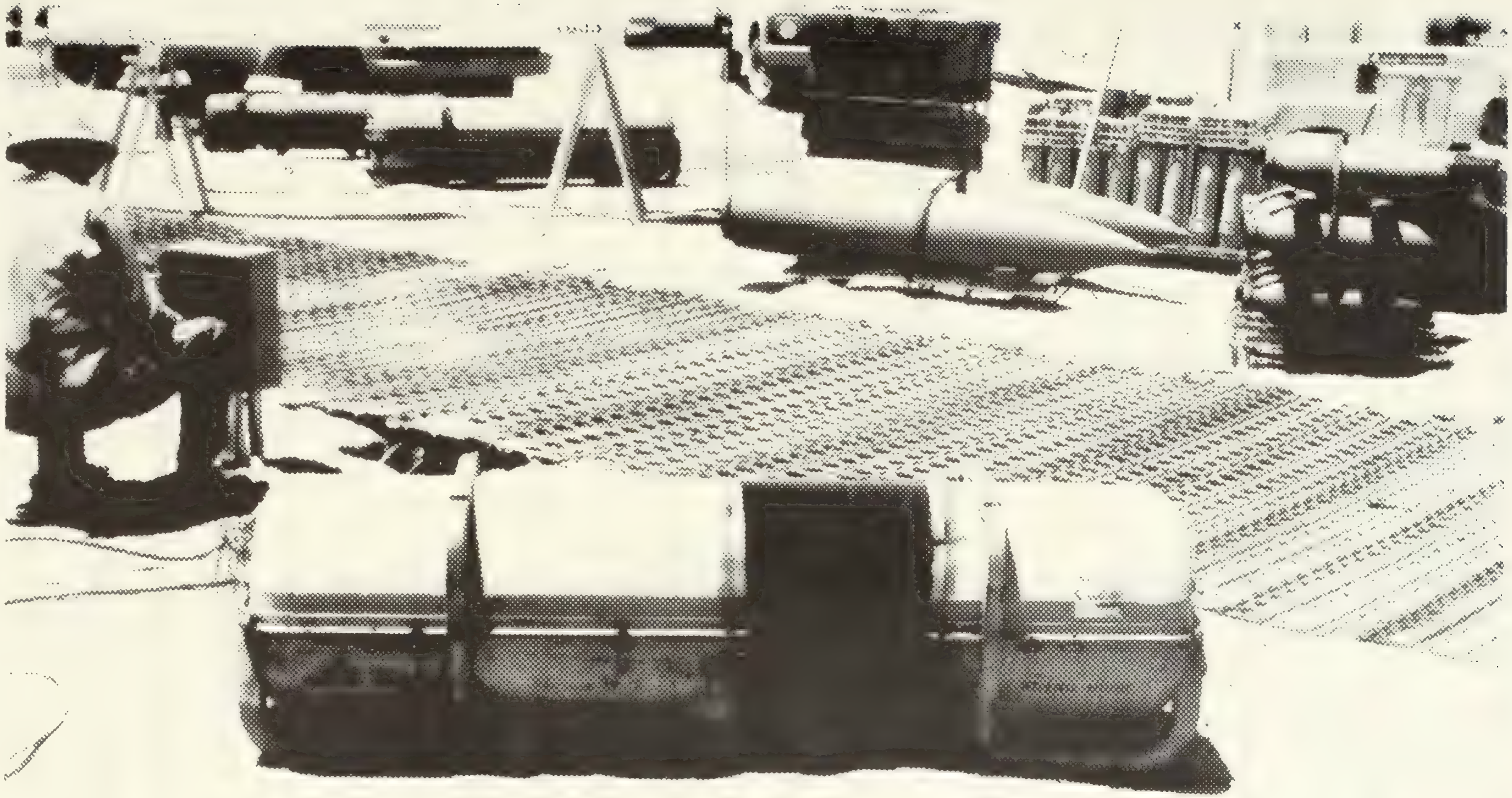

Figure 6. Experimental System at Dump Storage Site.

system was allowed two weeks to reach a periodic steady state before additional photographic data was obtained.

Extensive photographic data was collected on 27 and 28 July 1972 after two weeks of exposure to the desert environment. Both super 8 mm and 16 mm color movies and 35 mm color slides were taken of the liquid crystals. No colored filters were used on any of the cameras, although standard haze filters were used to take the super 8 mm movies and most of the 35 mm slides.

At this time, a second storage container, this one without a rocket motor inside, was instrumented with intrinsic thermocouples in the same manner as the previous container. As only three data channels remained open on the recorder, only three thermocouples were applied to this new container. The three thermocouples were applied at the 0300, 0900, and 1200 positions at the midpoint of the container. This container was set end to end with the system that was already in place at the site. The purpose of this study was to determine if the inclusion of the rocket motor in the container had a significant effect on the surface temperature of the container. Thermocouple #7 was connected at the 0900 position, #23 at the 1200 position, and #24 at the 0300 position. It was immediately apparent that thermocouple #7 was continuing to give unreliable readings and therefore the data taken on channel #7 was neglected.

IV. THEORETICAL ANALYSIS

A. ONE-DIMENSIONAL ANALYTICAL MODEL

The first step was to try to devise an analytical model that would simulate the actual rocket motor storage container experimental system. The first simplifying assumption was that the storage container temperature could be modeled by a sine wave which had a period of 24 hours. A comparison of the sinusoidal variation to the average (bulk) storage container temperature [obtained by averaging the four thermocouple readings on the surface of the container (1, 8, 10, and 12) as shown in Appendix D] is given in Figure 7.

The method of complex temperature as presented by Arpaci [Ref. 1] was used to find the steady periodic solution of a body experiencing a periodic sinusoidal disturbance. A complete analytical derivation is given in Appendix B. The general heat conduction equation in cylindrical coordinates was the basis for this derivation. It was assumed that there was one dimensional radial heat flow with no conduction in the axial or circumferential directions, that no heat sources existed in the model, that the rocket motor storage container system was infinitely long, and that the sinusoidally varying surface temperature was spacially uniform over the entire container surface. The storage container temperature is assumed to vary as

$$T_\infty = (T_M - T_A) \sin \omega t + T_A$$

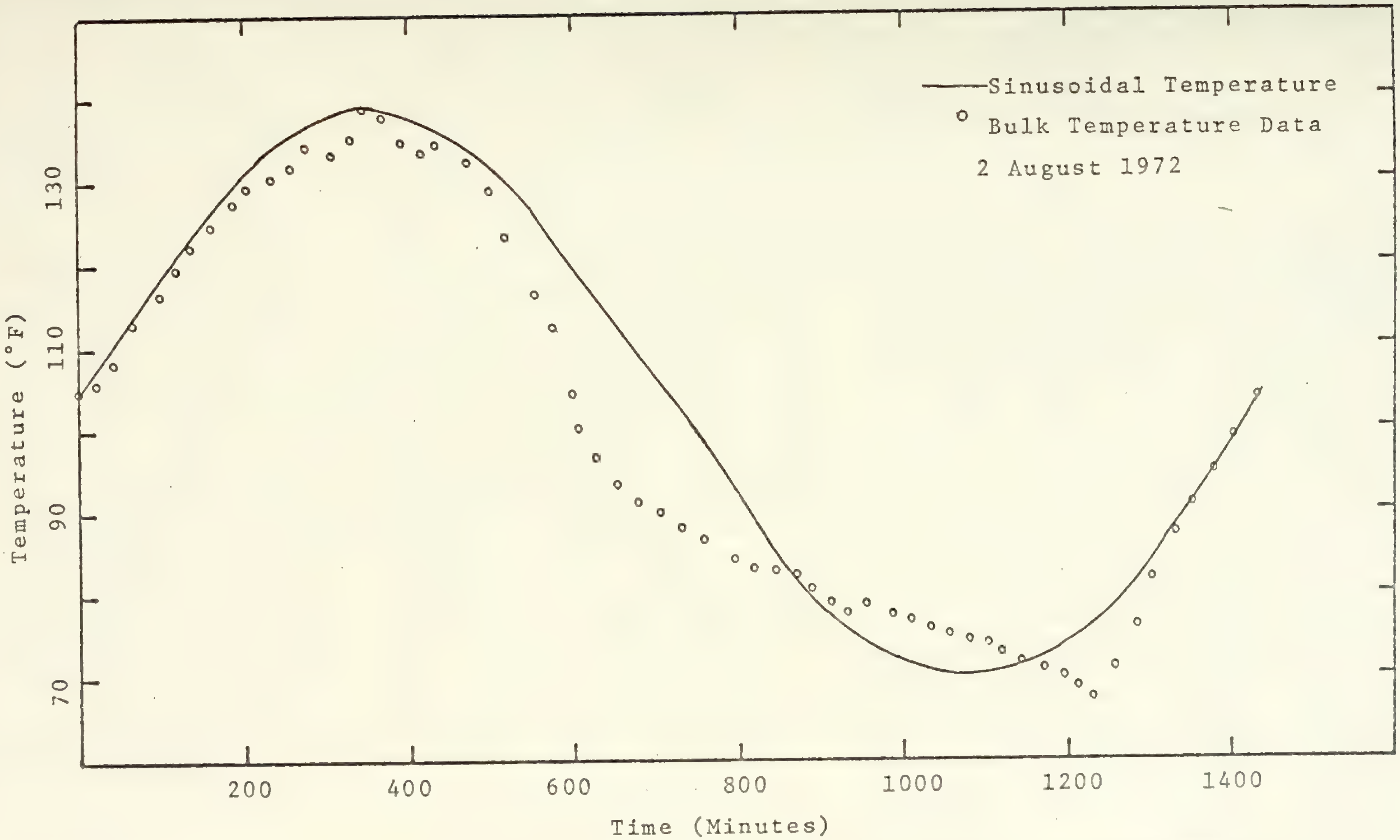

Figure 7. Comparison of Sinusoidal Temperature Variation to Bulk Temperature.

where T_M = maximum bulk temperature of the storage container
T_A = average bulk temperature of the storage container
ω = frequency of the sinusoidal variation (2π/24 hours)
t = time (hours)

It was assumed that all the thermal properties remained constant over the temperature range of the problem. The effective heat transfer coefficient, $\bar{h}$, across the air gap between the storage container and the rocket motor combines the heat transfer effects of radiation, convection, and conduction into one coefficient. The radiation coefficient was linearized by assuming constant representative temperatures in the equation

$$h_{RAD} = \mathcal{F}_{1-2}\sigma\ (T_1 + T_2)(T_1^2 + T_2^2)$$

where σ is the Stefan-Boltzmann constant and $\mathcal{F}_{1-2}$ is the radiation exchange factor. The convection coefficient is the effective conductivity of air, obtained from the Beckmann correlations [Ref. 5], divided by the width of the air gap. In the analytical model, the effective conductivity was assumed to equal the conductivity, thereby treating it as pure conduction and giving the equation

$$\bar{h} = h_{RAD} + h_{CON}$$

An initial condition was not specified in this derivation as the only concern was the steady-state, periodic behavior. The steady-state solution is (Appendix B)

$$\theta(r,t) = \frac{T(r,t)-T_A}{T_M - T_A} = \frac{\sqrt{BER_o^{\,2}(a\xi)+BEi_o^{\,2}(a\xi)}}{\sqrt{X_R^{\,2} + X_i^{\,2}}}\ \sin(\omega t+\delta^*)$$

$$\theta(r,t) = \theta_r\ \sin\ (\omega t + \delta^*)$$

where $T(r,t)$ = the temperature of a point r in the rocket motor at time t

$a = \sqrt{\frac{\omega r_o^2}{\alpha}}$ = conduction parameter

$\xi = \frac{r}{r_o}$ = dimensionless distance from the center of the rocket motor

r_o = inner radius of the rocket motor

r = distance from the center of the rocket motor

$\alpha = \frac{k}{\rho c}$ = thermal diffusivity

ρ = density

k = thermal conductivity

c = specific heat

BER = real Bessel Function

BEi = imaginary Bessel Function

$$X_R = BER_o(a) + \frac{a}{\sqrt{2}\beta} BER_1(a) + \frac{a}{\sqrt{2}\beta} BEi_1(a)$$

$$X_i = BEi_o(a) + \frac{a}{\sqrt{2}\beta} BEi_1(a) - \frac{a}{\sqrt{2}\beta} BER_1(a)$$

$\beta = \frac{\bar{h} r_o}{k}$ = Biot modulus

$$\delta^* = \tan^{-1} \frac{BEi_o(a\xi)X_R - BER_o(a\xi)X_i}{BER_o(a\xi)X_R + BEi_o(a\xi)X_i}$$

Two computer studies were done based on the steady state solution. The first study was a completely dimensionless situation which served as a parameter study of the effects of varying a and β on the temperature and the time lag of the temperature at various positions in the model.

$a = \sqrt{\frac{\omega r_o^2}{\alpha}}$ = conduction parameter

and

$\beta = \frac{\bar{h} r_o}{k}$ = Biot modulus

Parameter a was varied from 1.0 to 5.0 and β was varied from 0.1 to 100. These were the only values studied, as

only values within this range are of interest in this type problem. The computer program and its output are given at the end of Appendix B. The output lists the following values:

1) a, the conduction parameter
2) β, the Biot modulus
3) ξ, the non-dimensional distance from the center of the motor
4) δ^*, the time delay between the maximum storage container temperature and the maximum temperature reached at the point of interest in the motor
5) θ_r, the relative amplitude of the maximum temperature at the point of interest compared to the maximum temperature of the storage container

The time delay is given in radians, where 2π radians equals one complete cycle. A graph of the time delay versus β for a constant value of "a" is given in Figure 8 at three different positions within the motor. A graph of the relative amplitudes of the temperatures versus β for a constant value of "a" is given in Figure 9. It was noted that for a constant value of "a", the time delay decreased as β became larger. As the point of interest approaches the center of the rocket motor, the time delay increases. The relative amplitude of the temperatures also becomes larger as β is increased when the value of "a" is held constant. If β is held constant and "a" is varied, the time delay increases and the relative amplitude decreases as "a" increases.

The second study was obtaining the analytical solution to the particular rocket motor storage container system

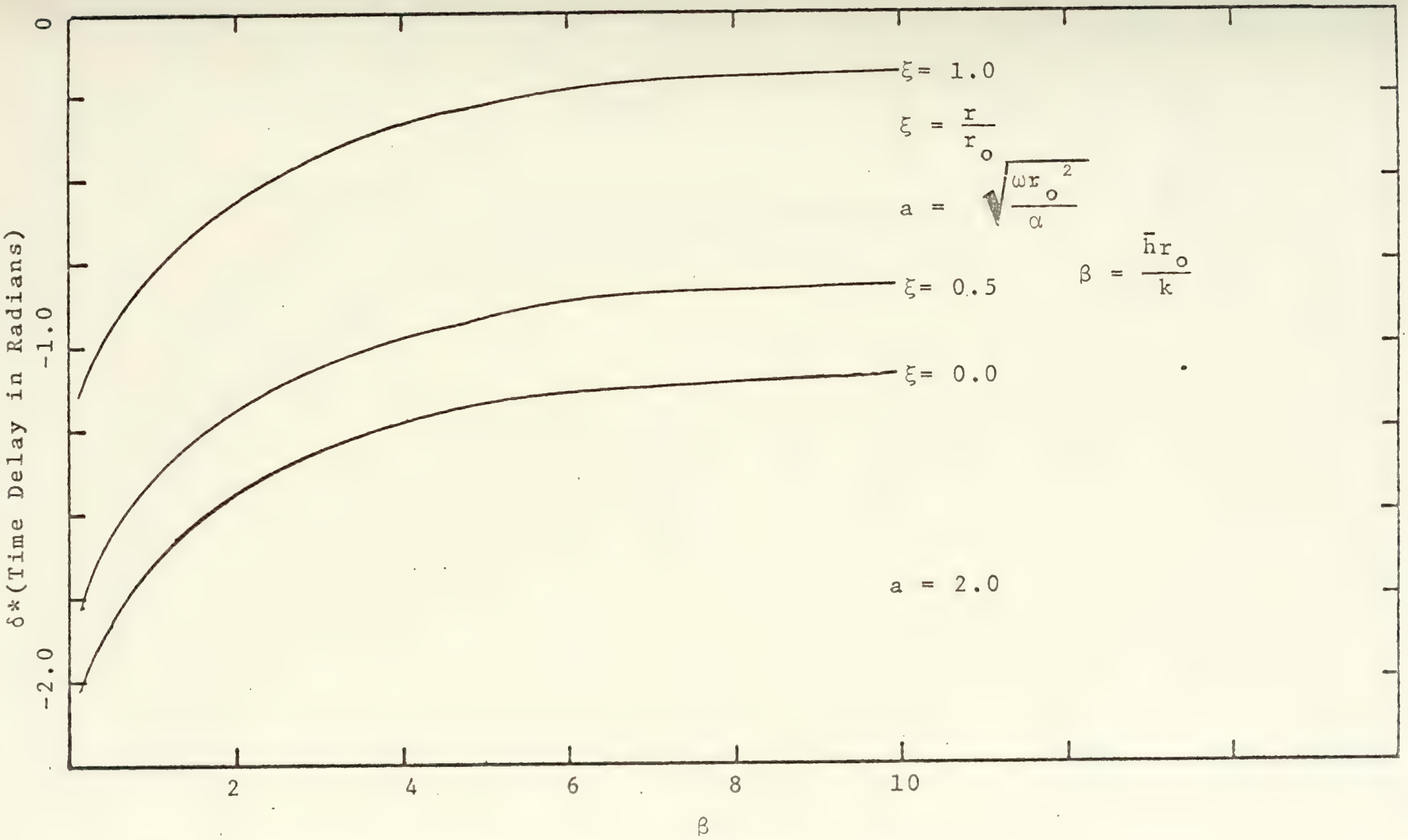

Figure 8. Variation in Time Delay with Change in Biot Modulus

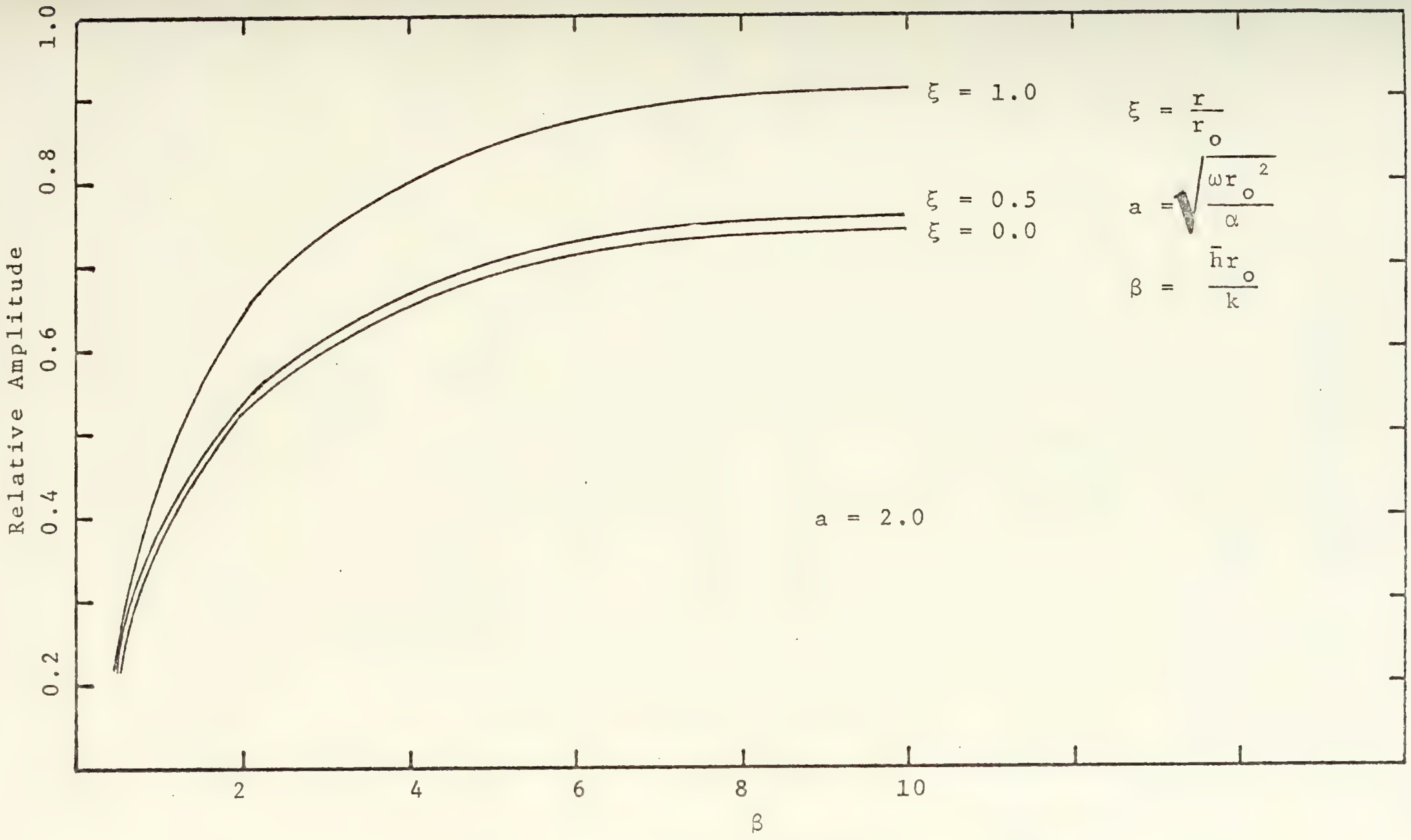

Figure 9: Variation in Relative Amplitude with Change in Biot Modulus.

studied at China Lake. The thermodynamic properties of dry sand were obtained from Ref. 6 as

$$\rho = 94.8 \text{ lbm/ft}^3$$
$$k = 0.188 \text{ BTU/hr ft °F}$$
$$c = 0.195 \text{ BTU/lbm °F}$$

Substituting these values and using 1440 minutes (24 hours) as a complete cycle, the parameters a and β were calculated for this model as

$$a = \sqrt{\frac{\omega r_o^2}{\alpha}} = 2.43$$

where r_o = 5.75 inches, the inner radius of the rocket motor.

$$\beta = \frac{\bar{h} r_o}{k} = 2.90$$

where $\bar{h} = h_{CON} + h_{RAD}$

and $h_{CON} = \frac{k_{AIR}}{\Delta r} = 6.48 \times 10^{-2} \frac{\text{BTU}}{\text{hr-ft}^2\text{°F}}$

where Δr = 2.94 inches, the distance across the air gap

and $k_{AIR} = 1.62 \times 10^{-2} \frac{\text{BTU}}{\text{hr ft°F}}$

$$h_{RAD} = \mathcal{F}_{1-2}\sigma(T_1 + T_2)(T_1^2 + T_2^2) = 1.09 \frac{\text{BTU}}{\text{hr ft}^2\text{°F}}$$

where σ is the Stefan-Boltzmann constant, $\mathcal{F}_{1-2}$ is the radiation exchange factor which for this geometry is

$$\mathcal{F}_{1-2} = \frac{1}{\frac{1}{\varepsilon_1} + \frac{r_1}{r_2}(\frac{1}{\varepsilon_2} - 1)} = 0.84$$

when $\varepsilon_1 = \varepsilon_2 = .9$, $r_1 = 6.0$, $r_2 = 8.94$

therefore $\bar{h} = 1.15$ BTU/hr ft^2°F

The average surface temperature of the storage container was found to be 104°F for a particular day at China Lake,

with a maximum temperature of 138°F. These values were obtained by averaging the readings of thermocouples 1, 8, 10, and 12 as shown in Appendix D which give the bulk temperature.

The temperatures of seven positions within the rocket motor were calculated and the results are printed at 30 minute intervals for one complete cycle in Appendix B. A graph of temperature versus time was plotted by the computer showing the relationship between the surface temperature of the storage container (TINF), the temperature on the outer skin of the rocket motor (TEDG), and the temperature at the center of the motor (TCEN). This graph is Figure 10.

B. TRUMP MODEL

The rocket motor storage container system at China Lake was modeled on TRUMP, a numerical conduction code, (See Appendix C for a description of the TRUMP program) to predict the temperature at any point in the system from a knowledge of the storage container surface temperature variation, the thermal properties and the geometrical details of the system. Two models were used to simulate the rocket motor storage container system and several variations of each model were investigated.

The first model assumed one dimensional heat transfer (radial). The system was modeled as two infinitely long concentric steel cylinders, the inner of which was filled with dry sand. A 2.94 inch air gap separated the cylinders. The model was subdivided into concentric volumetric elements

with representative nodal points as given in Figure 27, Appendix C. It was assumed that the storage container surface temperature was spacially uniform. From the data given in Appendix D and the observation of the liquid crystals' thermal mapping, it was obvious that the temperature distribution on the storage container was not spacially uniform. In order to simulate a spacially uniform condition, the readings of the thermocouples located at the 1200, 0300, 0600, and 0900 positions (#1, 8, 10, and 12) were averaged and this average value of the surface temperature (referred to as the bulk temperature) was used as the spacially uniform temperature distribution. Two methods were used to describe the container temperature. The first method used the maximum bulk temperature (138°F) and the average bulk temperature (104°F) of the storage container to generate a sine wave with a period of 24 hours (1440 minutes). The second method took the bulk temperature readings at two hour intervals and fed this data into the TRUMP program in a tabular (temperature versus time) form. The version of TRUMP used in this problem was limited to a table length of 12 tabular values. TRUMP interpolated between the tabular points. Figure 11 compares the actual bulk data with the sinusoidal approximation and the interpolated tabular values.

Several assumptions were made to simplify the solution of this problem. As the thermocouple data from the storage container gave an average value of the temperature across the 1/16 inch steel wall, node 12 was modeled as a zero

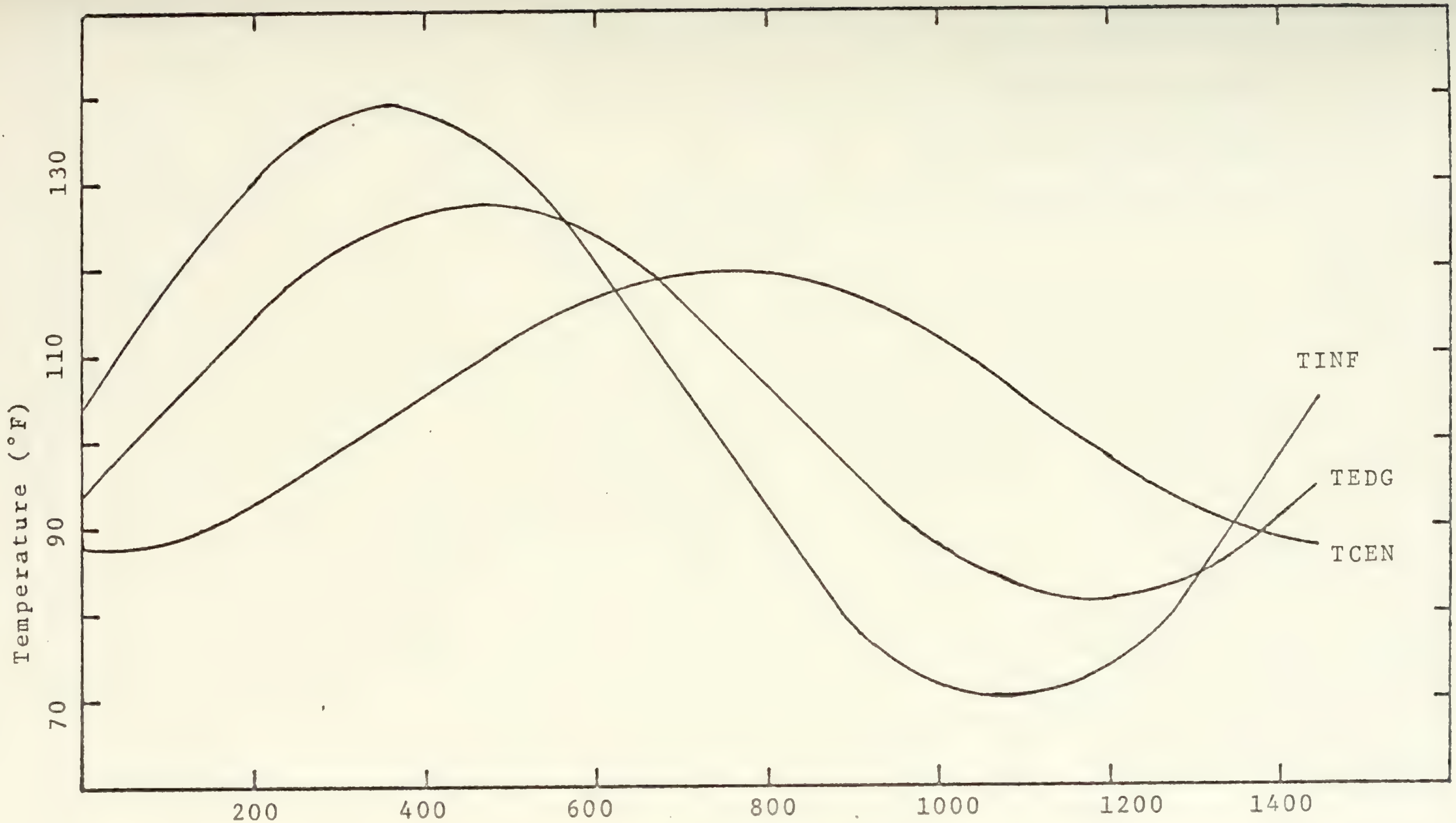

Figure 10: Analytical Prediction of Temperature Variation with Time, where TINF is the surface temperature of the storage container, TEDG is the surface temperature of the rocket motor, and TCEN is the temperature at the center of the motor.

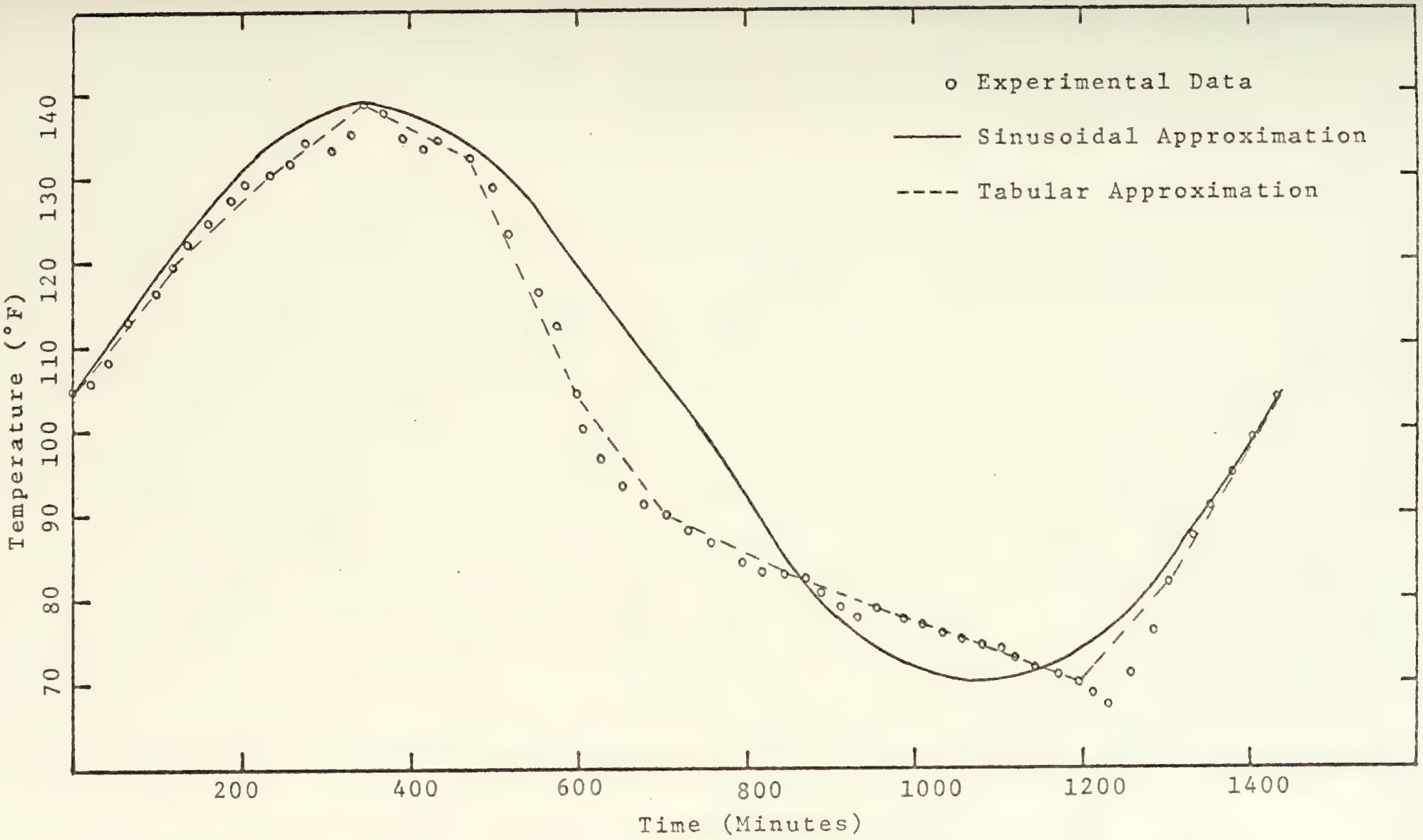

Figure 11: Comparison of Bulk Temperature to Two TRUMP Approximations.

volume boundary node with a known temperature impressed upon it. It was also assumed that heat transfer across the air gap occurred by radiation and conduction alone. Free convection effects were initially neglected. This assumption was later modified to investigate the free convection effects. All surfaces of the storage container and the outside surface of the rocket motor were painted various shades of haze gray and it was estimated that the emissivity of these surfaces was 0.9. The radiation exchange factor, $\mathcal{F}_{1-2}$, for this model was the same as that for the analytical solution ($\mathcal{F}_{1-2} = 0.84$). It was also assumed that there was perfect thermal contact between the rocket motor and the sand that filled it. This neglects the possibility that the sand might slightly settle after being on the site for a long period of time.

The second model assumed two dimensional heat transfer (radial and circumferential). The same physical model was used as in the one dimensional case with the sole exception that 48 nodes were used instead of 12. The representative nodal points and an example of the thermal connections from one of the nodal points are shown in Figure 28 in Appendix C. The four nodes on the surface of the storage container were modeled as zero volume boundary nodes. The sinusoidal and tabular representations were used to describe the surface temperature of the storage container at each boundary node. Actual data taken at each position, rather than bulk data, were used as the input data for these representations.

The same assumptions made in the one dimensional case were also applicable to the two dimensional model. A complete discussion of the calculation of the radiation exchange factors in the two dimensional case is given in Appendix C.

The effect of natural convection was studied in both the one and two dimensional models. References 5 and 7 give correlations between the Grashof number based on the gap width and the effective thermal conductivity. The Grashof number was calculated from the equation

$$Gr = \frac{\rho^2 g B (\Delta T) \delta^3}{\mu^2}$$

where δ = width of the air gap

ΔT = maximum temperature difference at any instant of time in the air gap

$B = \frac{1}{T}$ where $T = 565°R$

At $T = 565°R$, air has the following properties

$\rho = 0.07$ lbm/ft^3

$\mu = 0.046$ lbm/hr-ft

The maximum Grashof number for this experiment was calculated to be 1.25×10^6. The diameter ratio was approximately 1.5 and the log Gr = 6.1. From the Beckmann correlation [Ref. 5], the effective thermal conductivity ratio $(\frac{k_c}{k})$ was approximately 3.2. Using the Liu correlation [Ref. 7]

$$\frac{k_c}{k} = 0.135 \left(\frac{Pr^2 Gr_\delta}{1.36+Pr}\right)^{0.278} = 4.5$$

where the Prandtl Number = 0.707. An effective thermal conductivity of 4.0 was assumed as the average value of these

two correlations and it was used to study the effects of free convection. This change was placed into the TRUMP program by increasing the value of the thermal conductivity of air by a factor of 4 in each of the TRUMP runs.

V. RESULTS

A. ANALYTICAL MODEL

Using the sinusoidal temperature distribution as an approximation to the actual average experimental data as shown in Figure 7, comparisons were made between predicted temperatures and actual temperatures for two radial locations in the rocket motor. Figure 12 compares the results on the surface of the rocket motor and Figure 13 does the comparison at the center of the rocket motor. An uncertainty analysis is given in Appendix E which establishes the uncertainty bounds for both the predicted and the actual temperatures. These uncertainty bounds are included in Figures 12 and 13.

It is readily seen from Figure 7 that a sine wave was not an ideal fit as an approximation to the experimental data, as it varies as much as 20°F during part of the cycle. However, it was also noted that the sine wave closely approximated the experimental data during the heating phase of the cycle and only during the cooling phase were there large variations. As the main purpose of this study was to design a model that would be useful in optimizing storage container design, the errors in the cooling phase are not critical as long as the temperatures reach the same minimum point before beginning another cycle. Figure 12 shows that the maximum surface temperature of the rocket motor predicted by the analytical model is a good approximation to the actual

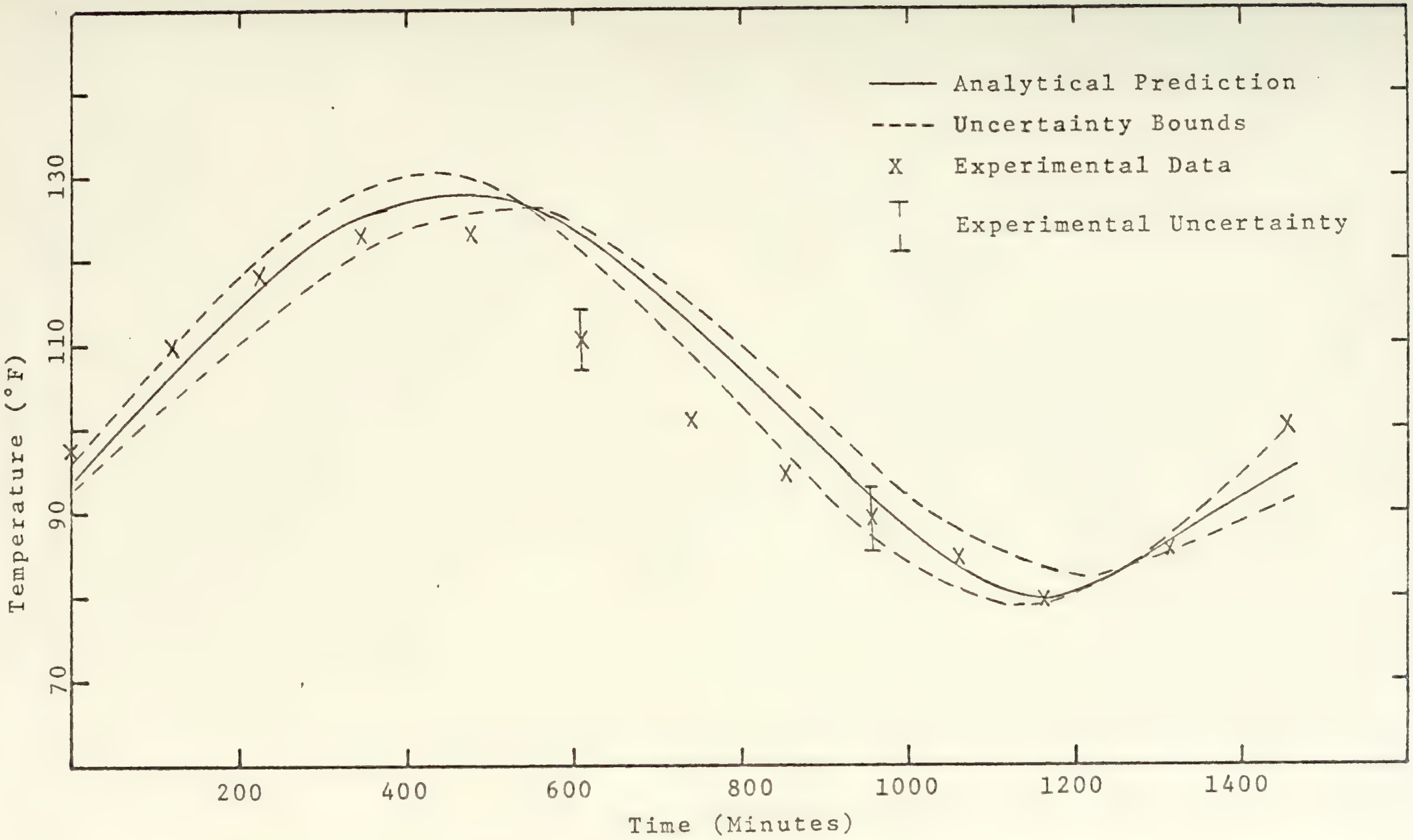

Figure 12: Comparison of Analytical and Experimental Temperatures at Surface of Rocket Motor.

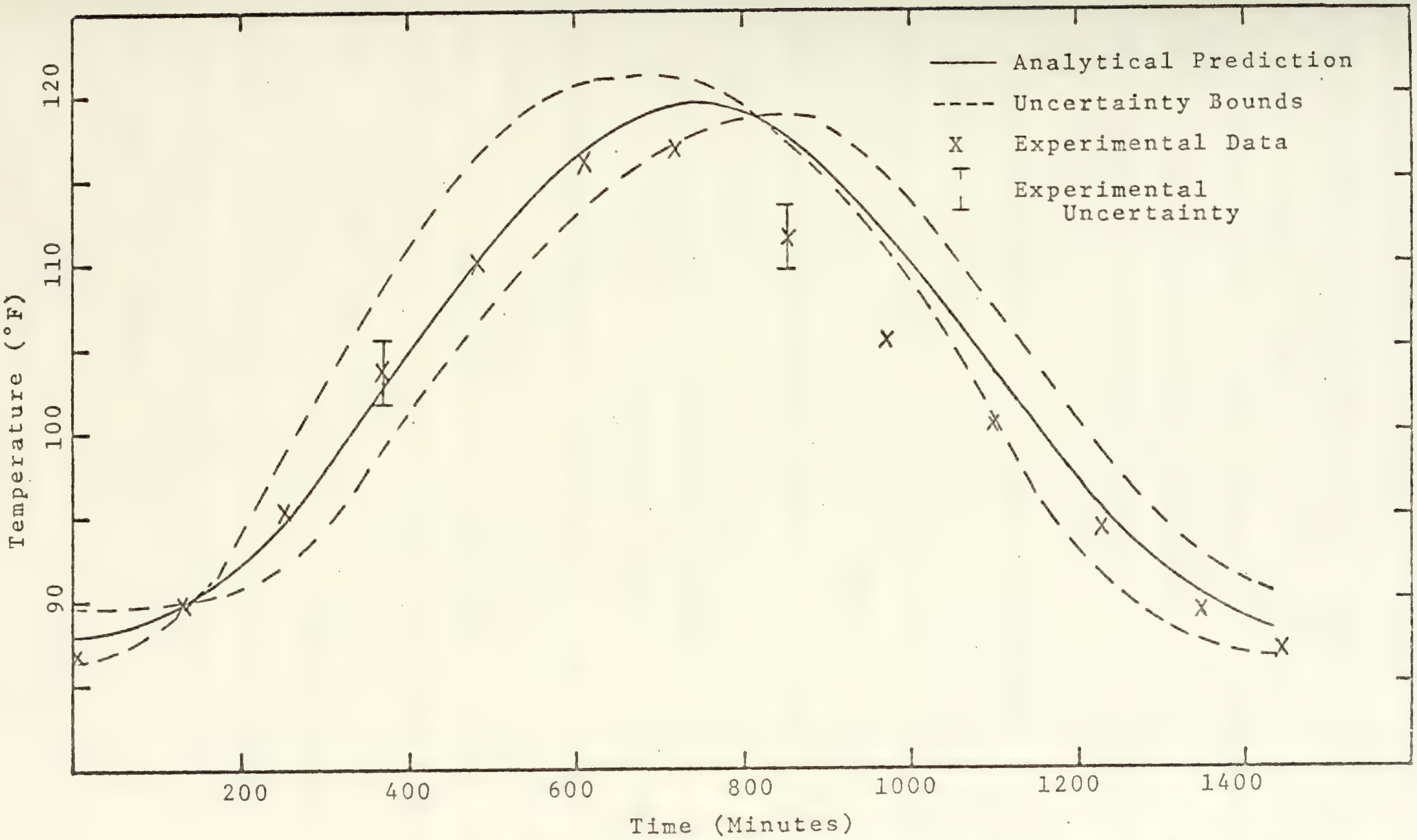

Figure 13: Comparison of Analytical and Experimental Temperature at Center of Rocket Motor.

experimental data. Again it is noted that, in actuality, the motor cools faster than the predicted value. The maximum difference in temperatures on the surface of the motor is 15°F. Figure 13 shows that the predicted value and the experimental value of the temperature at the center of the rocket motor were in close approximation except during the early stages of the cooling phase where a maximum temperature variation of about 5°F occurred.

One of the reasons the system cools faster than predicted could be the light breeze that is usually evident in the early afternoon hours at China Lake that is not present during the morning. No attempt was made to shield the system from the wind to study the effects of a light breeze on the surface temperature of the storage container.

Another point not taken into account by the analytical model is the fact that the time delay at any point in the system is not constant throughout the day as predicted in Figure 10, but varies as given by the data in Appendix D. Time delays between the peak temperature on the container surface and the peak temperature at the center of the rocket motor vary from about 250 to 400 minutes, whereas the low temperature on the surface of the container and the low temperature at the center of the rocket motor vary from about 150 to 250 minutes. The analytical model predicts a constant variation of 388 minutes at the center of the rocket motor and 159 minutes at the surface.

B. TRUMP MODEL

1. One Dimensional

Four variations of the one dimensional TRUMP model were investigated and compared to the experimental data. Figures 14 and 15 compare the TRUMP predictions to the actual experimental data at the surface and the center of the rocket motor,respectively. The TRUMP variation used for this comparison modeled the storage container temperature with tabular data (See Figure 11) and assumed convection was present ($\frac{k_c}{k} = 4.0$). The uncertainty analysis (Appendix E) established the uncertainty bounds for both the experimental and the analytical data in these Figures. The variation between the bulk temperature predicted by TRUMP and the experimental data closely matches with only two experimental points in Figure 14 falling outside the uncertainty bounds for this one dimensional model. Figure 11 shows that the tabular data that TRUMP interpolates is a good approximation to the averaged experimental data. At the center of the motor, as shown in Figure 15, all experimental points fall within the predicted error bounds. A comparison of the four one-dimensional TRUMP variations are given in Figures 16 and 17 at the surface and the center of the rocket motor respectively. It is clearly seen from these Figures that the convection assumption results in an increase of 2°F in the maximum temperature and a decrease of 2°F in the minimum temperature on the surface of the rocket motor. This temperature change drops to ± 1.5°F at the center of the

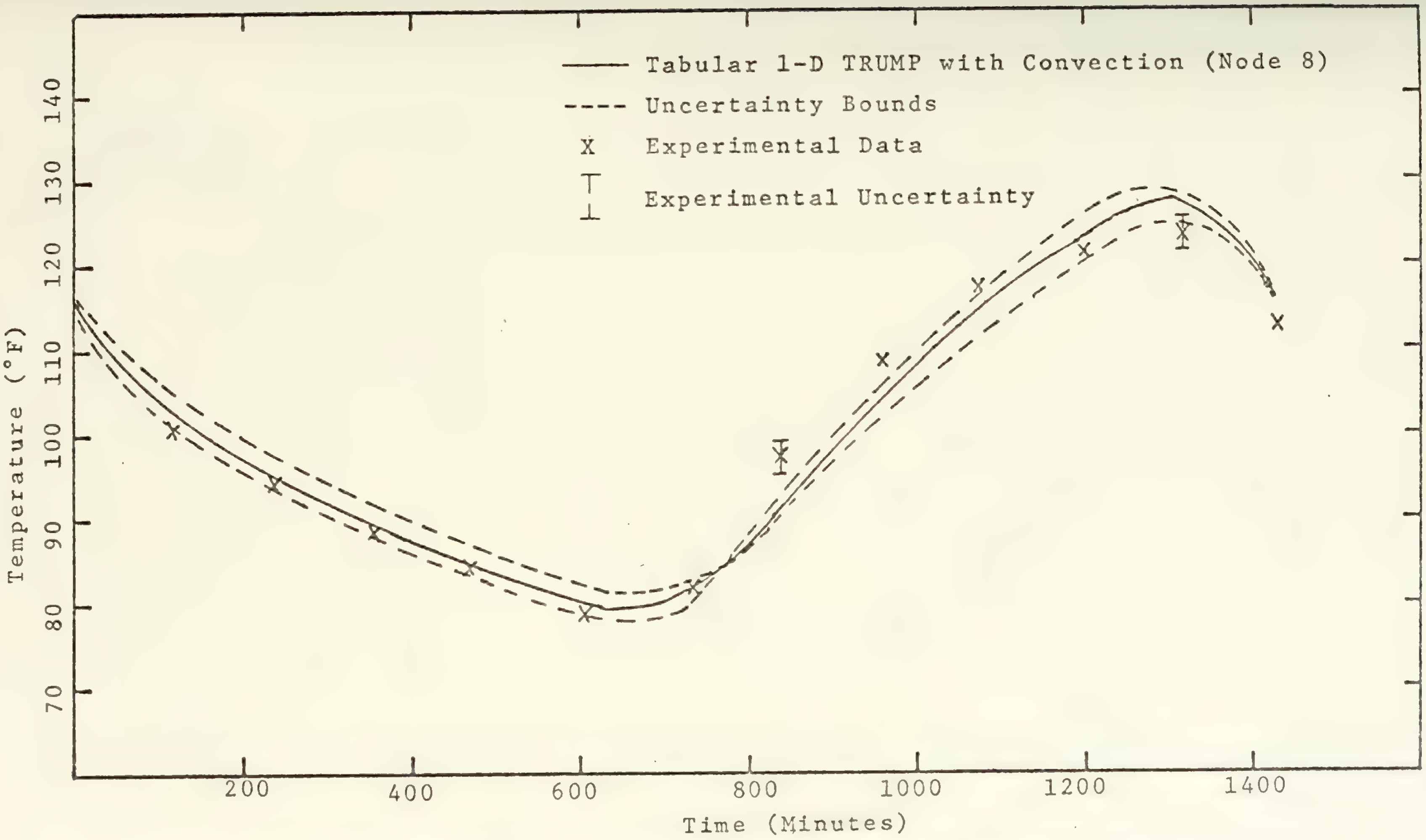

Figure 14: Comparison of 1-D TRUMP and Experimental Temperatures at Surface of the Rocket Motor.

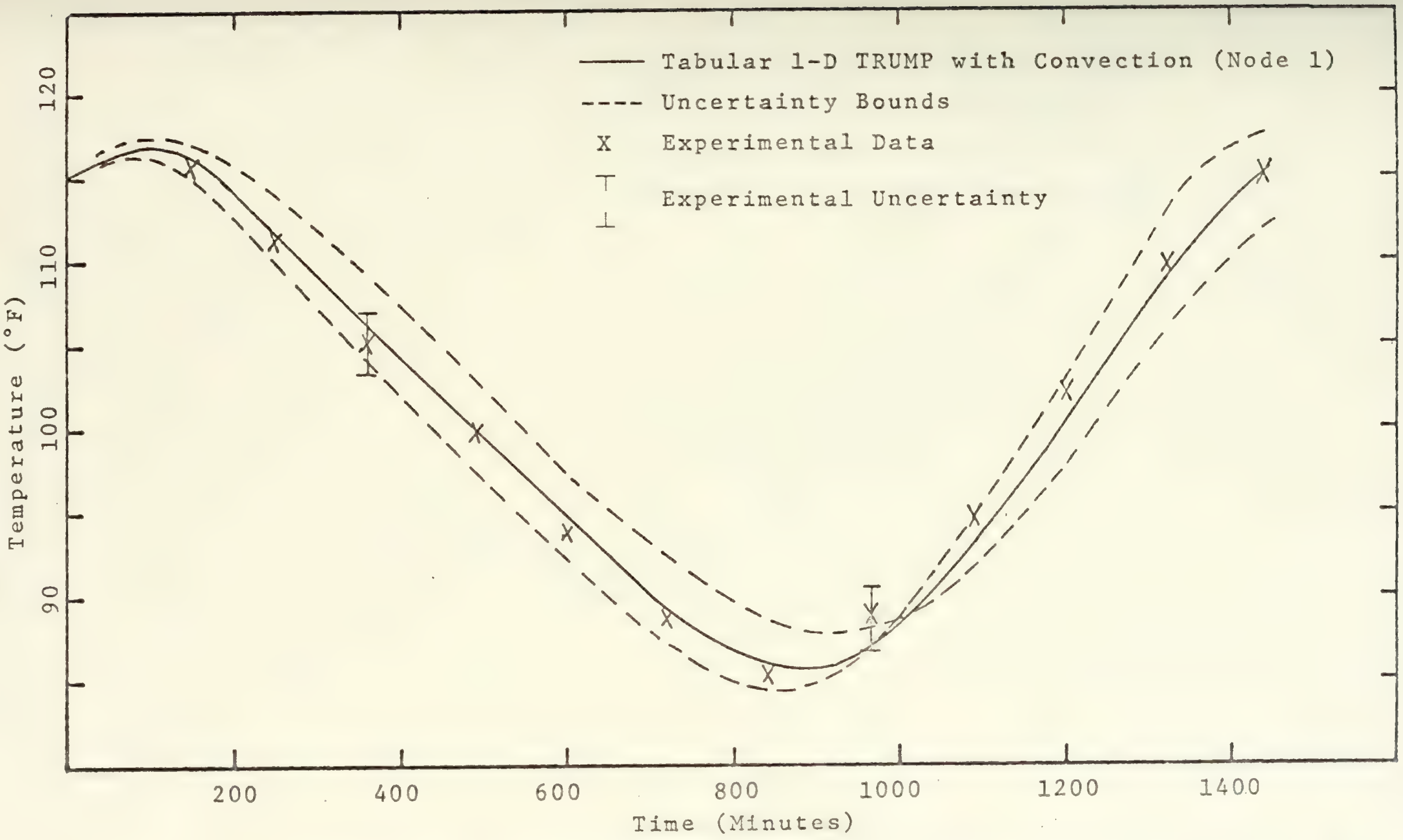

Figure 15: Comparison of 1-D TRUMP and Experimental Temperatures at Center of Rocket Motor.

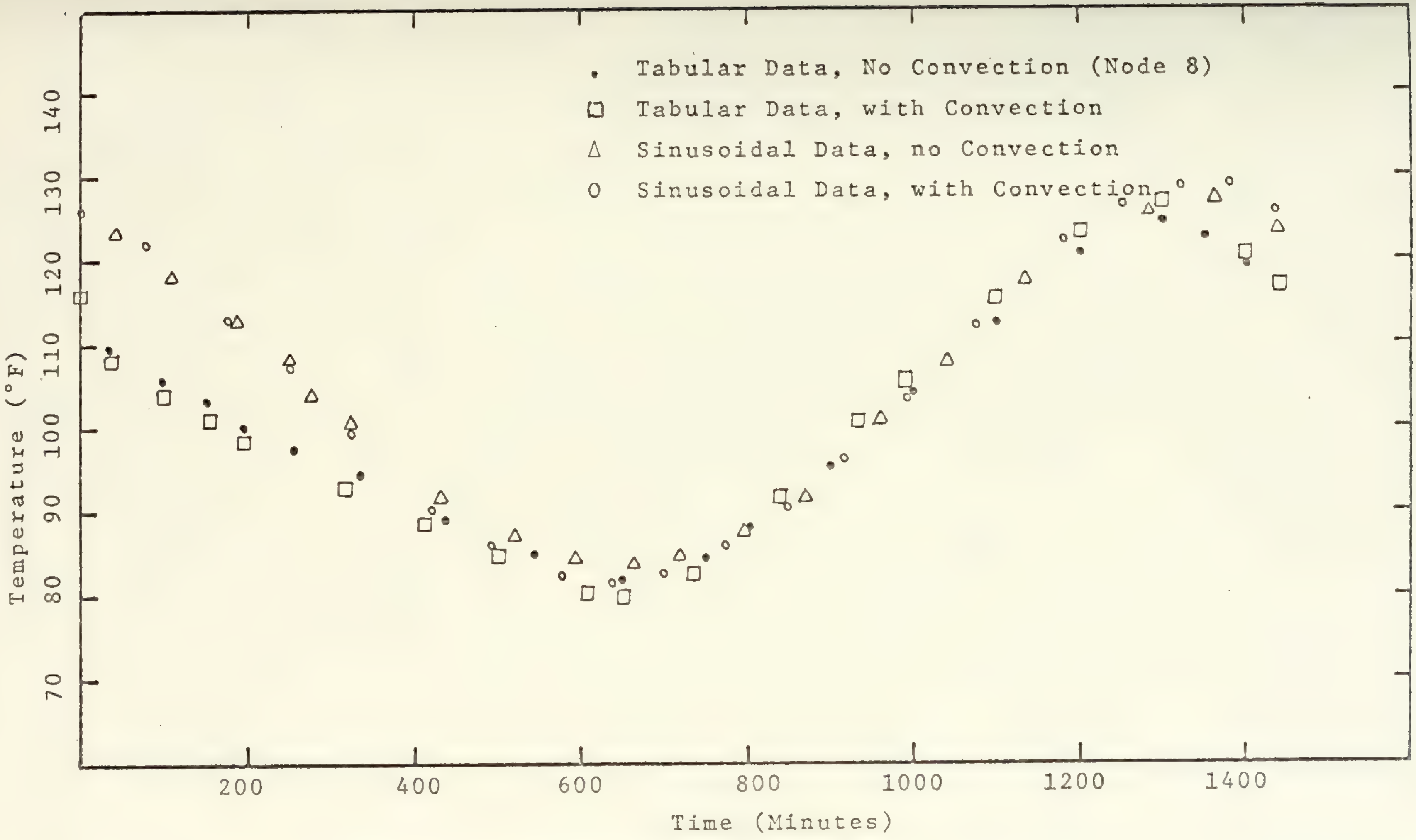

Figure 16: Comparison of Temperatures from Four 1-D TRUMP Variations at Surface of Rocket Motor.

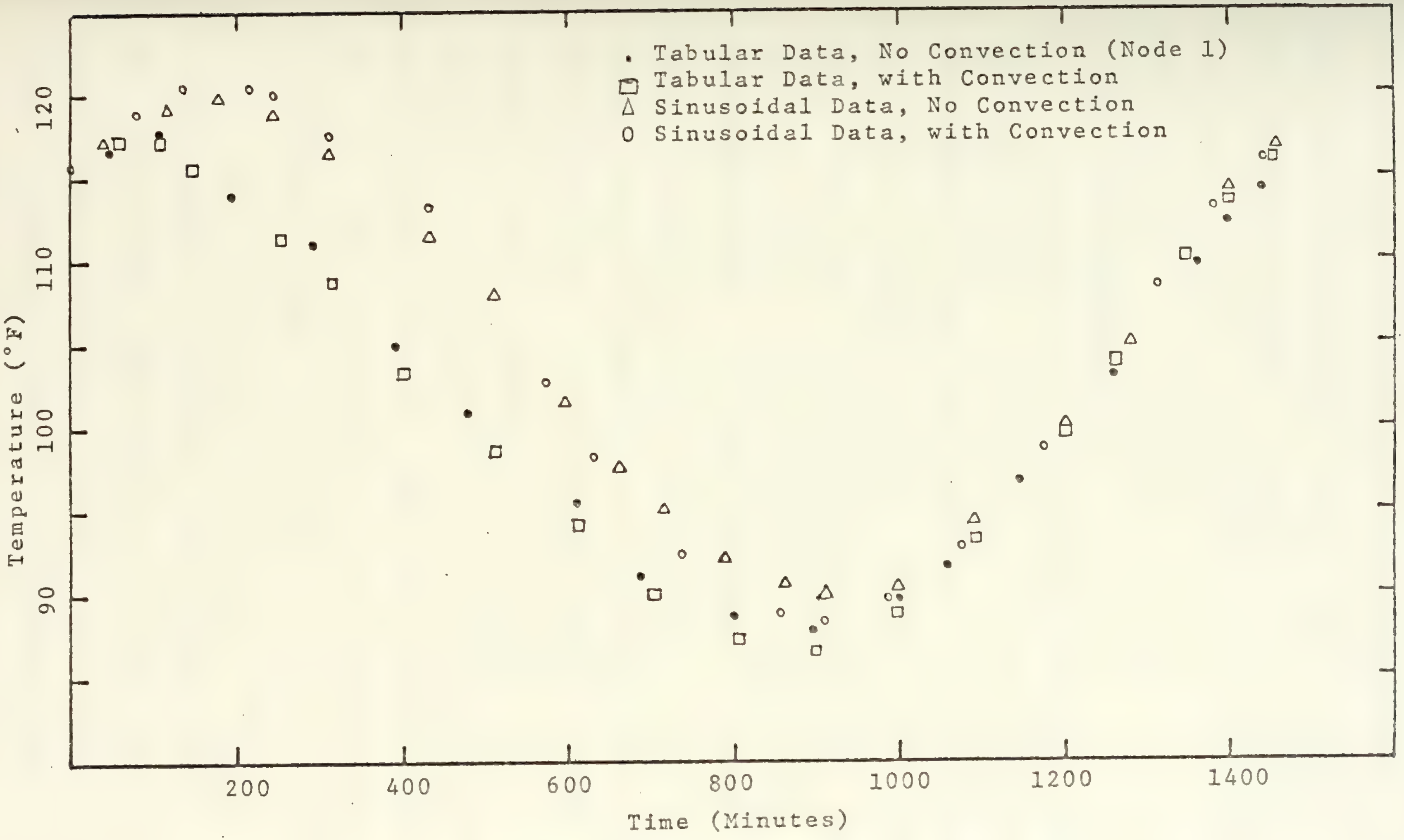

Figure 17: Comparison of Temperatures from Four 1-D TRUMP Variations at Center of Rocket Motor.

motor as shown in Figure 17. The differences between the sinusoidal approximation and the tabular approximation of the experimental data was clearly shown in Figure 11. The data in Figures 16 and 17 can be easily correlated to that in Figure 11, thereby explaining the differences in the predicted values.

2. Two Dimensional

Four variations of the two dimensional TRUMP model were investigated and compared to the experimental data. Comparisons of each TRUMP variation to the experimental data are given in Figures 18 and 19 for node 8 (located on the skin of the rocket motor at the 1200 position) and node 1 (at the center of the rocket motor) respectively. These Figures show that the TRUMP variations that used tabular data to model the surface temperature of the storage container predicted temperatures that more closely approximated the experimental values than were those predicted by TRUMP variations using sinusoidal data to model the surface temperature. Appendix D shows that all points on the surface of the storage container reach their minimum temperature at the same time; however, these points reach their maximum temperature as much as 200 minutes apart. Whereas, all the points on the surface of the storage container are in phase at the minimum temperature, they rapidly become out of phase as the container temperature rises. This varying phase shift makes it difficult to model the four boundary nodes with sinusoidal approximations which must have constant

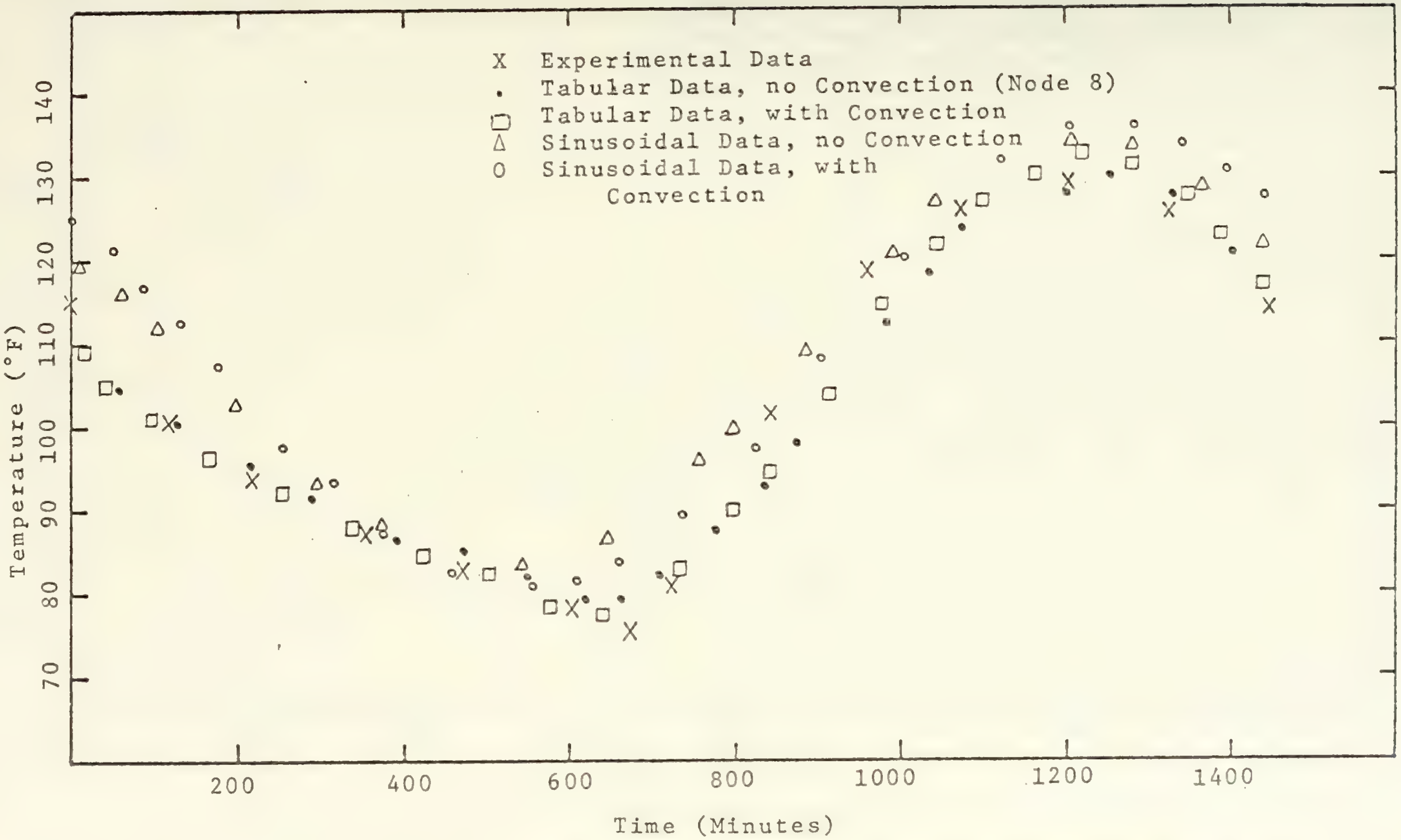

Figure 18: Comparison of 2-D TRUMP and Experimental Temperatures at Surface of Rocket Motor.

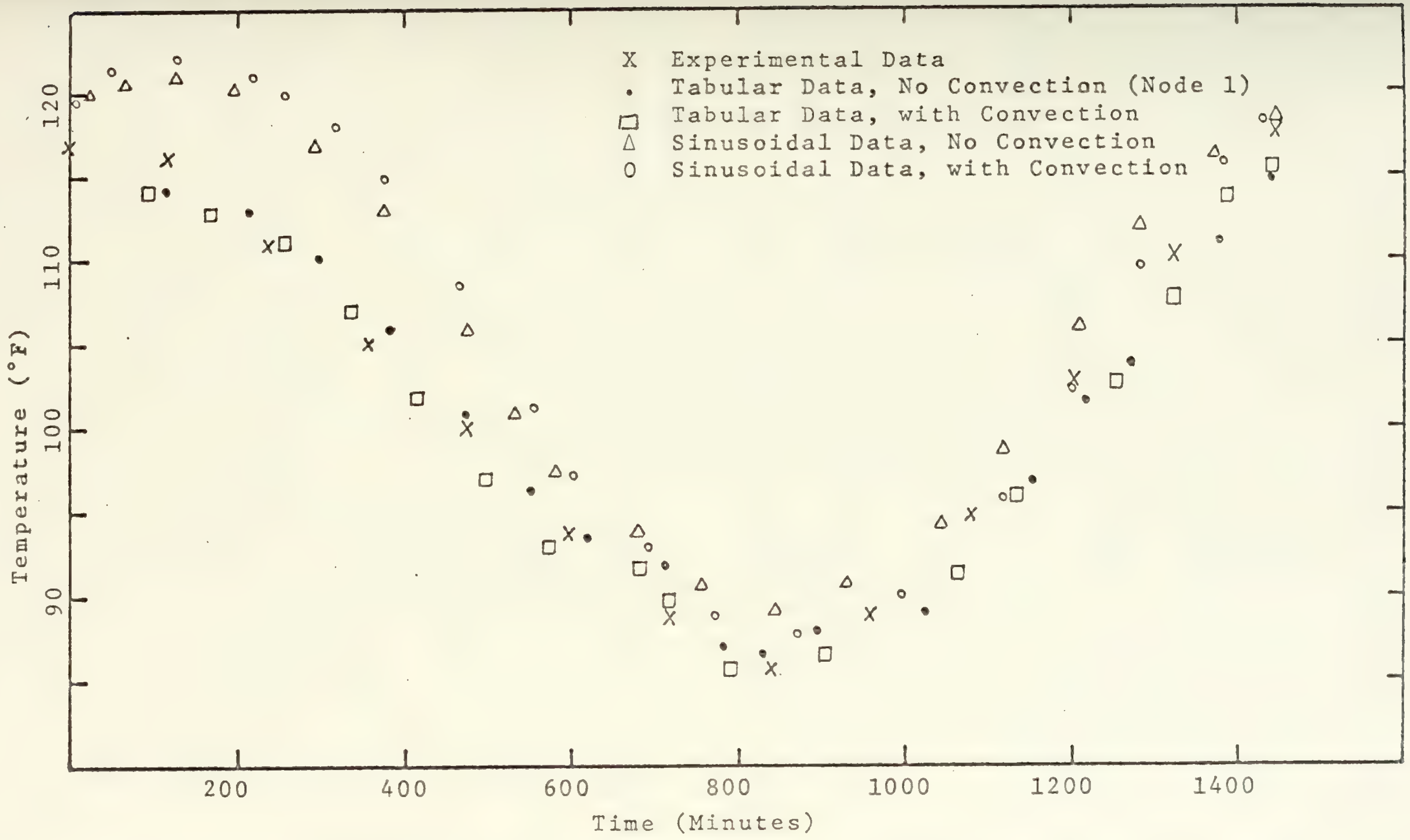

Figure 19: Comparison of 2-D TRUMP and Experimental Temperatures at Center of Rocket Motor.

phase shifts. Sizable errors in the input data during some parts of the cycle were caused by these varying phase shifts. These errors in the input data led to the variations in the predicted temperature values. As noted in the one dimensional section, the inclusion of convection effects does not produce large variations in the predicted temperatures.

Figures 20 and 21 show the actual temperature distributions on the surface of the storage container and on the surface of the rocket motor respectively at maximum bulk temperature compared to a two dimensional TRUMP program. The TRUMP variation used for this comparison assumed no free convection in the air gap and used tabular data to approximate the surface temperature of the storage container.

C. GENERAL

A comparison was made between surface temperatures on the storage container that contained the rocket motor and the storage container that was empty. The low temperature was about 4°F colder in the empty container, whereas the high temperature was about 4°F higher on the container that contained the rocket motor. The empty container had a faster response time than the one containing the motor. The differences in heat capacities, radiation effects, and natural convection all contribute to the changes in temperature noted.

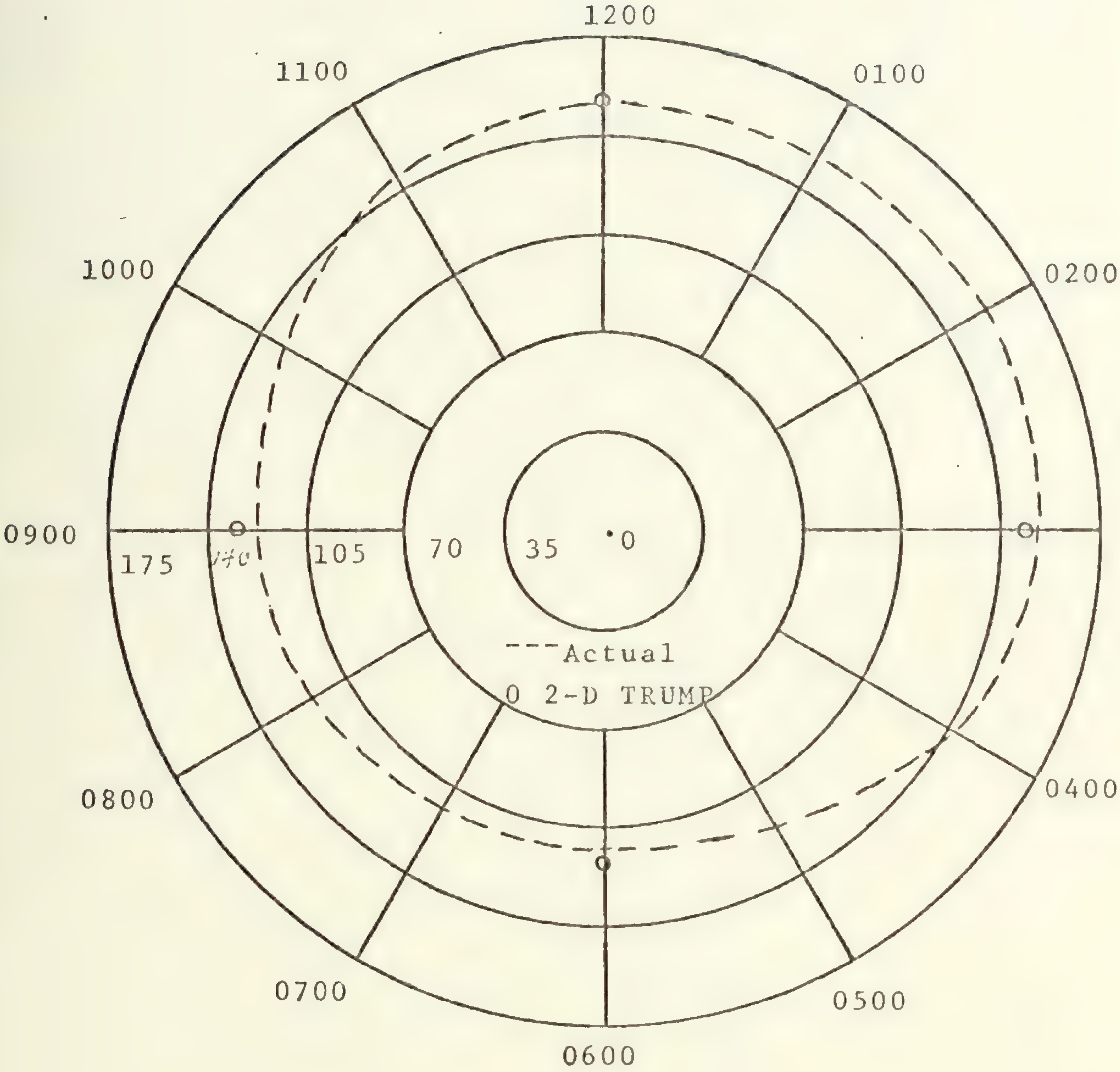

Figure 20: Temperature Distribution at Surface of Storage Container at Maximum Bulk Temperature at approximately 1500 on 2 August 1972.

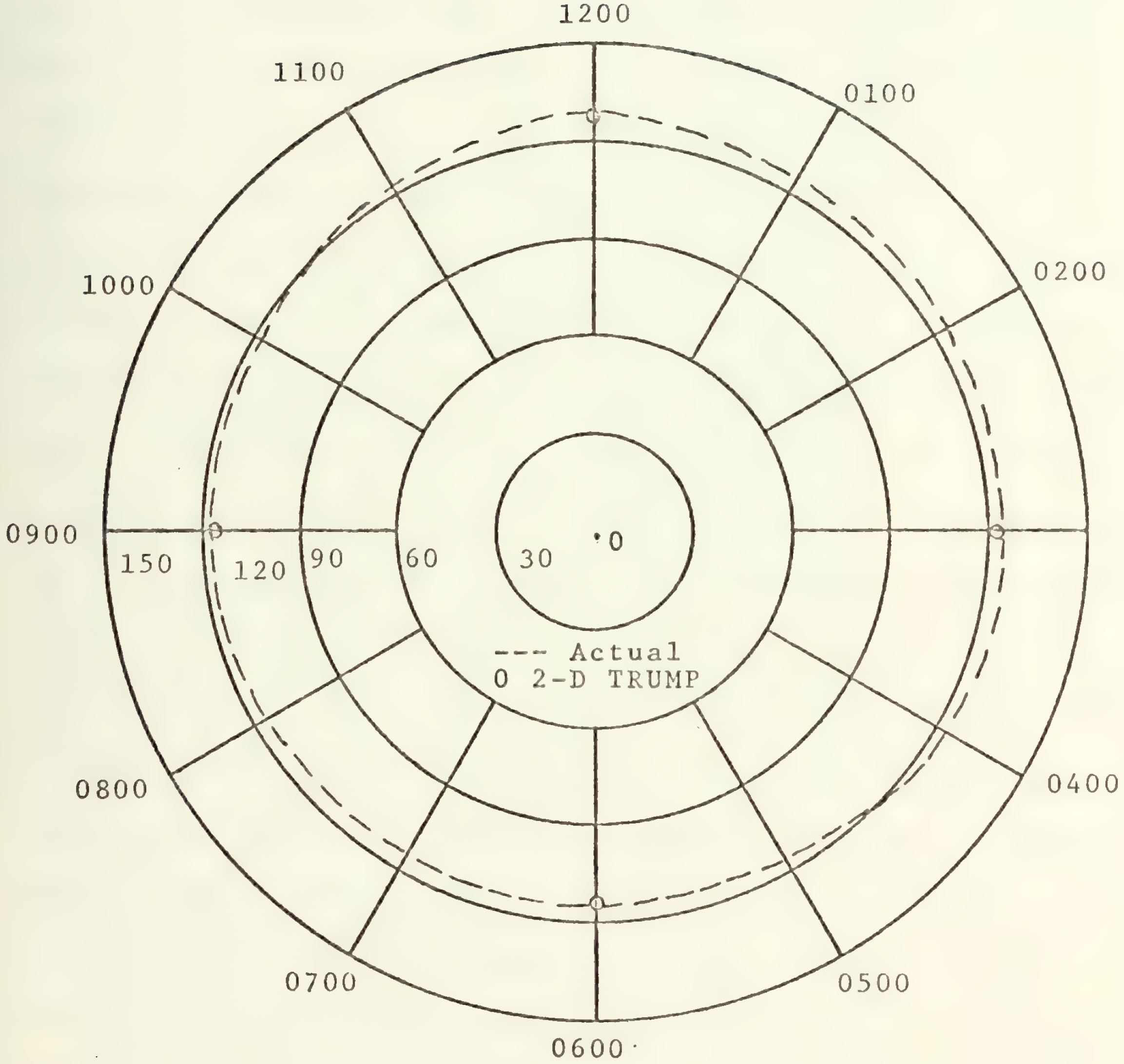

Figure 21: Temperature Distribution at Surface of the Rocket Motor at Maximum Bulk Temperature at approximately 1500 on 2 August 1972.

D. LIQUID CRYSTALS

The encapsulated cholesteric liquid crystals applied to the surface of the storage container gave brilliant colors under the intense desert sun. These colors were much clearer and brighter than the same crystals viewed under laboratory lighting conditions. The liquid crystals photographed well in both the color movies and the color slides. The movies showed by time lapse photography the rapidly changing surface temperature of the storage container. Two sample color prints made from the color slides are enclosed as Figures 22 and 23 to show the brilliance of the colors and the feasibility of obtaining data from color photos. The only photographic problem encountered was the intense reflection of the sunlight from the polyurethane film. This problem was partially overcome by taking the photographs from angles where the reflection was less intense. Qualitatively the liquid crystals were not adversely affected by the sun's rays after two weeks of desert exposure. No accurate quantitative determination was attempted; however, rough approximations were made at the site. These approximations were made by noting the color exhibited by a crystal at a certain time and then comparing the calibration of the crystal (Table 1) to the temperature recorded by the thermocouple located directly beneath the region of color change. The readings were within ± 2°F, which was very encouraging, especially considering the approximations made while taking these measurements. Although photos were taken only during

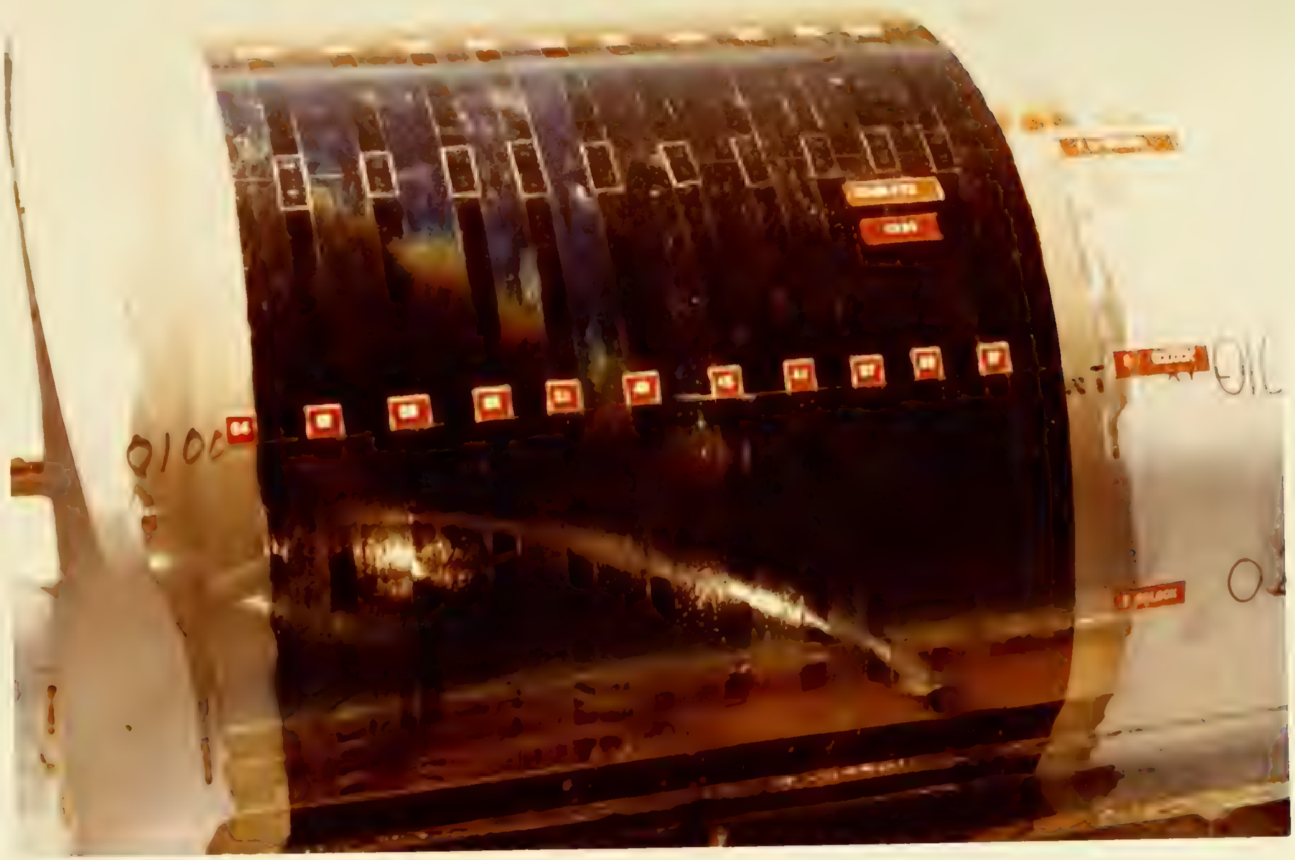

Figure 22. Thermal Mapping with Liquid Crystals.

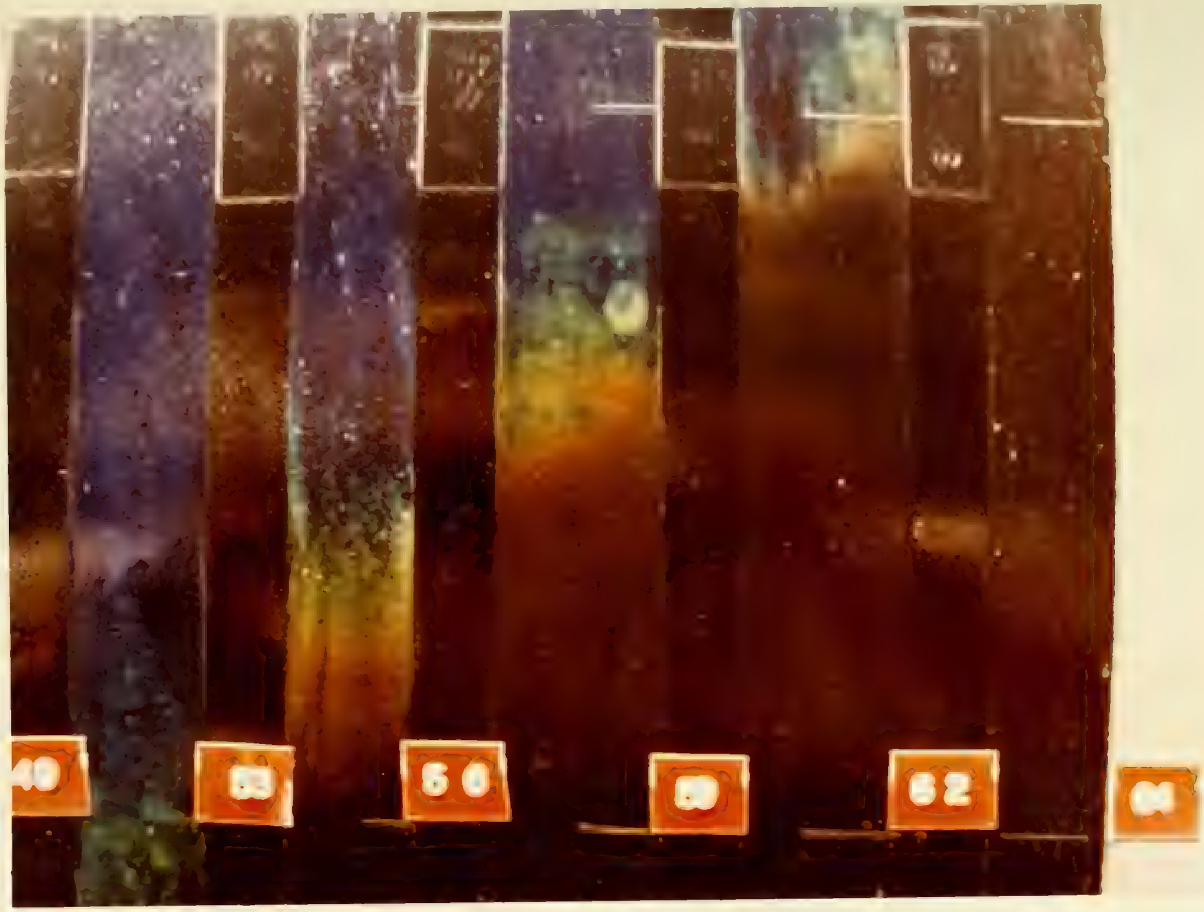

Figure 23. Liquid Crystals Feasible Under Hostile Environment.

the initial two weeks of the study, on site observations indicate that the crystals are still showing brilliant colors after 3-1/2 months. Preliminary evidence indicates that the polyurethane film did protect the crystals from decomposing from the sun's rays and from being worn away by the wind blown sand.

It was noted that the surface temperature of the storage container under the liquid cyrstals reached temperatures up to 15°F higher than a similar point not under the crystals. This 15°F difference was only evident when maximum temperatures were obtained. During sunlight hours the temperature under the liquid crystals was always somewhat higher; however, at night both temperatures were equal. The difference in the container surface temperatures led to a difference of 4°F on the surface of the rocket motor and 1°F at the center of the motor. It is believed that the difference in emissivities of the gray and black surfaces resulted in the difference in container surface temperature.

VI. CONCLUSIONS

From the results of this investigation, the following conclusions were drawn:

1. Although a sine wave is not a perfect fit for the experimental data at all points, it is useful in predicting bulk temperatures in the rocket motor, especially if only the high and low bulk temperatures are of concern. This is especially true in the one dimensional case. In the two dimensional case, the problem of phase shift variations make the method of sinusoidal variation less desirable, although still useful.

2. The simulation of the actual data by a table of temperatures gave the most accurate predictions of the experimental data. This method should be used whenever tabulated data are available; however, this will generally not be the case for design work, in which case the sinusoidal approximations must be used.

3. The flexibility of both the analytical and computer simulations allow the changing of many parameters. The resulting effects of these changes on rocket motor temperature can be studied with the models.

4. The convection assumption for this system resulted in only small changes in temperature and can be neglected when predicting design temperatures. Either the Liu or Beckmann correlation should be used to determine if convection can be neglected in a particular system.

5. The use of an empty storage container to obtain surface temperature data is a good approximation to using one with a rocket motor inside.

6. It is feasible to use liquid crystals for thermal mapping under desert conditions. Color photography with standard equipment gives excellent results since brilliant colors were observed.

7. The liquid crystals appear to be stable for at least two weeks under the desert conditions when protected with a polyurethane coating.

8. The application of the liquid crystal system to the surface of the storage container resulted in large increases in the surface temperature of the container throughout the hottest part of the day. Care must be taken in applying and interpreting thermal readings from liquid crystals when exposed to radiant heating.

VII. RECOMMENDATIONS

From the results of this basic study, the following recommendations for future work are offered:

1. To refine the results of this project, a second rocket motor storage container system should be instrumented with the following changes:

    a. Liquid crystals should not be applied to the system used as the experimental model. As steel is a good thermal conductor, axial conduction on the surface of the storage container may be significant. Heat flow from the area where the crystals are applied may lead to higher than normal temperatures at other points on the surface of the container.

    b. The rocket motor should be weighed before and after the loading of the dry sand so that an accurate determination of the density of the propellant simulant can be determined.

    c. Four additional thermocouples should be located on the surface of the storage container to better enable the averaging of data. At present, the #1 thermocouple which was used as the average temperature reading of the top quarter of the surface of the container, in actuality is its hottest point; likewise the #10 thermocouple was used as the average temperature of the bottom quarter of the surface, in actuality it's the coldest point. For averaging data, it is recommended that thermocouples be placed at 0130,

0430, 0730, and 1030 and the quarters of the system be divided at 0300, 0600, 0900, and 1200 to give a more realistic bulk temperature. Thermocouples at 1200 and 0600 will provide the maximum and minimum temperature of the system.

2. The TRUMP program should be rerun in both the one and two dimensional form, varying the mesh sizes to determine the optimum number of nodes.

3. A long term study of the effects of the desert environment on liquid crystals should be done. The crystals should be calibrated before being placed in the desert and then brought to a laboratory for recalibration at specific intervals.

4. Several modifications should be made to the TRUMP program to make it comparable to the version used at Lawrence Radiation Laboratory. The variable conductivity section (BLOCK 2) and the PLOT subroutine (BLOCK 11) need to be corrected. The TIMEP subroutine which allows the setting of the problem time interval between data output should be added to this version of TRUMP. It would also be advantageous to increase the amount of tabular data that could be read in as boundary temperatures.

5. From an academic standpoint, the effects of free convection in an air gap with varying boundary temperatures should be investigated.

APPENDIX A

Introduction to Liquid Crystals

Liquid crystals were first discovered in 1889 by Reinitzer [Ref. 8] and the investigations of Lehmann which continued to 1915. Liquid crystals were considered to be laboratory curiosities with no scientific or practical merit until the 1950's. They share some of the properties of both liquids and crystals; for example, a typical liquid crystal substance scatters light in symmetrical patterns and reflects different colors depending on the angle from which it is viewed. Studies in the last few years have helped to clarify the unusual molecular structure of liquid crystals. Many applications arise from their ability to detect minute fluctuations in temperature, mechanical stress, electromagnetic radiation and chemical environment by changes in their color.

Liquid crystals are divided into three classes; smectic, nematic, and cholesteric, depending on the degree of spatial arrangement of the molecules in the mass of the material and the type of the material [Ref. 9]. In this project only cholesteric liquid crystals were used and therefore only their properties will be mentioned. The molecular structure of cholesteric liquid crystals is characteristic of the esters of cholesterol (Figure 24). The molecular layers are very thin with the long axis of the molecules parallel to the plane of the layers. The individual molecules are

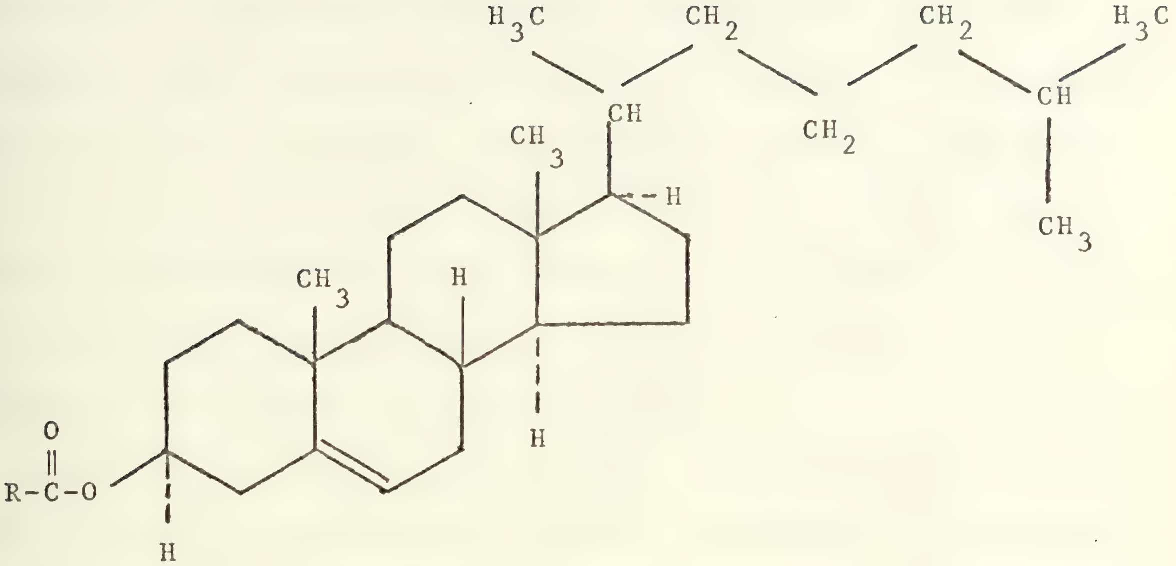

Figure 24: Molecular Structure of Cholesteric Ester

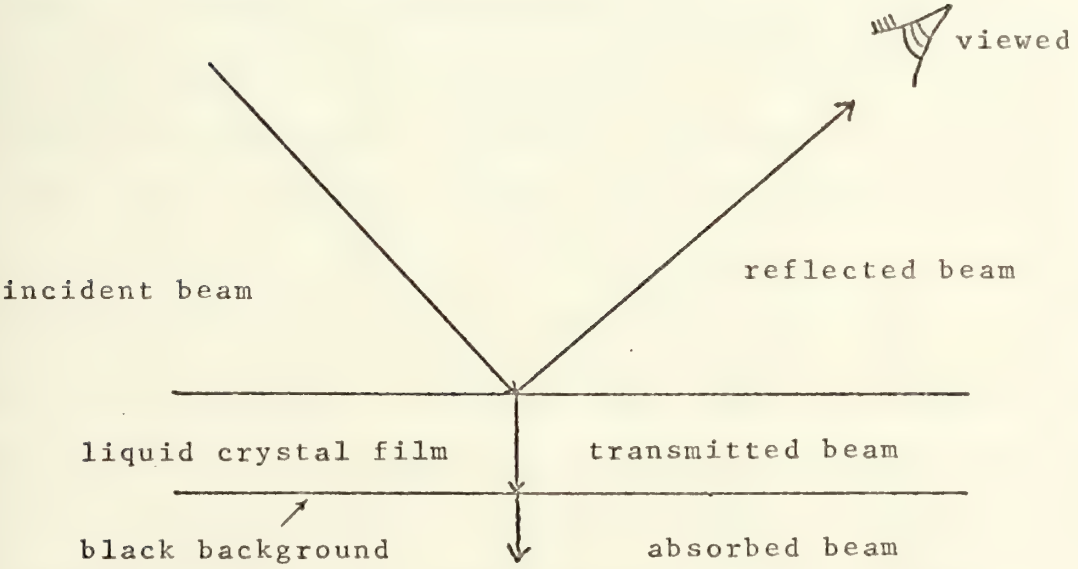

Figure 25. Light Reflection from Liquid Crystals.

basically flat, with a side chain of methyl groups ($-CH_3$) projecting upward from the plane of each molecule. This configuration causes the direction of the long axis of the molecules in each layer to be displaced slightly from the corresponding direction in adjacent layers. This displacement, which averages about fifteen minutes of arc per layer, is cumulative through successive layers, and the overall displacement traces out a helical path.

The molecular structure of cholesteric liquid crystals gives rise to many peculiar optical properties. If linearly polarized light is transmitted perpendicularly to the molecular layers, the direction of the electric vector of the light will be rotated to the left in a helical path. Therefore, the plane of polarization will also be rotated to the left, through an angle proportional to the thickness of the transmitting material. Liquid crystals are the most optically active substances known. Another strictly crystalline optical property exhibited by cholesteric liquid crystals is circular dichroism. When ordinary white light is incident to a cholesteric material, the light is separated into two components, one with the electric vector rotating clockwise, the other rotating counterclockwise. Depending on the material, one of these components is transmitted, and the other is reflected. It is this property that gives the cholesteric phase its iridescent color when it is illuminated by white light. The particular combination of colors depends on the material, the temperature, and the angle of the incident light.

The molecular structure of a cholesteric substance is very delicately balanced and is easily upset. Any small disturbance that interferes with the weak forces between the molecules can produce marked changes in optical properties such as reflection, transmission, birefringence, circular dichroism, optical activity and color. The most striking optical transformation that occurs in a cholesteric substance, in response to small changes in its environment, is the variation of color with temperature. The crystal lattice is disrupted by the thermal vibrations giving successive transitions between the solid, the mesophase, and the isotropic liquid with rising temperature. The change from the three dimensional order of the crystal lattice to the disorder of the isotropic liquid occurs via one or more intermediate states, each of which has a particular temperature range at which it is stable [Ref. 10].

A cholesteric liquid crystal system responds to changes in temperature by sequentially passing through the complete visual spectrum (red through violet) in fractions or multi-degrees, depending on which cholesterol esters comprise the formulation. This color phenomenon is reversible and has been reported to function over a temperature range of -20°C to 250°C. A very important point to note is that at a certain temperature a given material or combination of materials will always exhibit the same color. Also, the rate of change from color to color as well as the exact temperature at which the specific color changes occur are invariable. By

mixing cholesteric substances in various proportions, any desired temperature combination can be obtained. The thickness of the cholesteric film does not affect the predominant wave length of the reflected light; the light becomes circularly polarized [Ref. 11].

The colors scattered by the liquid crystals represent only a fraction of the incident light (Figure 25). The remaining portion of the incident light is transmitted by the liquid crystals. Therefore, an absorptive black background must be used to prevent reflection of the transmitted light, thereby enhancing the resolution of the scattered colors or wavelengths reflected by the liquid crystal system.

The cholesteric liquid crystal systems often present a number of problems due to the fact that they are viscous liquids. Some problems associated with the handling and the use of these materials are:

1. The tendency of the liquid crystal system to flow during application can cause variations in applied film thickness. This may result in non-uniform thermal patterns.

2. Direct exposure of liquid crystals to adverse environmental effects can cause variations in their sensitivity and deteriorate their color response in a few days.

These problems can be partially overcome by using an encapsulated liquid crystal material system. The capsules are 20-30 microns in diameter and are a water-based slurry suitable for application by conventional coating techniques such as brushing or spraying.

Encapsulated liquid crystals offer several advantages:

1. They convert the liquid crystal system to a pseudo-solid, which provides for easier handling, application, and use.

2. They provide longer shelf life by minimizing surface contamination and giving protection from ultraviolet light [Ref. 12].

3. They exhibit relatively unlimited fatigue life.

4. They reduce the angular dependence of the color observed.

APPENDIX B

Analytical Solution

The method of complex temperature as presented by Arpaci [Ref. 1] was used to find the steady periodic solution of a body experiencing a periodic sinusoidal disturbance. The general heat conduction equation in cylindrical coordinates was the basis for this derivation. It was assumed that no heat sources existed in this problem, that the rocket motor storage container system was infinitely long, that there was no heat conduction in the axial or circumferential directions, and that the container surface temperature was spacially uniform. Figure 26 gives a basic sketch of the system. The assumptions reduced the heat conduction equation to

$$\frac{1}{r}\frac{\partial\left(r\frac{\partial T}{\partial r}\right)}{\partial r} = \frac{1}{\alpha}\frac{\partial T}{\partial t} \qquad (1)$$

where r is the radial distance from the center of the rocket motor, T is the temperature of the rocket motor at time t and position r, and α is the thermal diffusivity, a property of the conducting material.

$$\alpha = \frac{k}{\rho c} \qquad (2)$$

where k is the thermal conductivity of the conducting material, ρ is the density of the material, and c is the specific heat. All thermal properties were assumed to be constant over the temperature range of this problem.

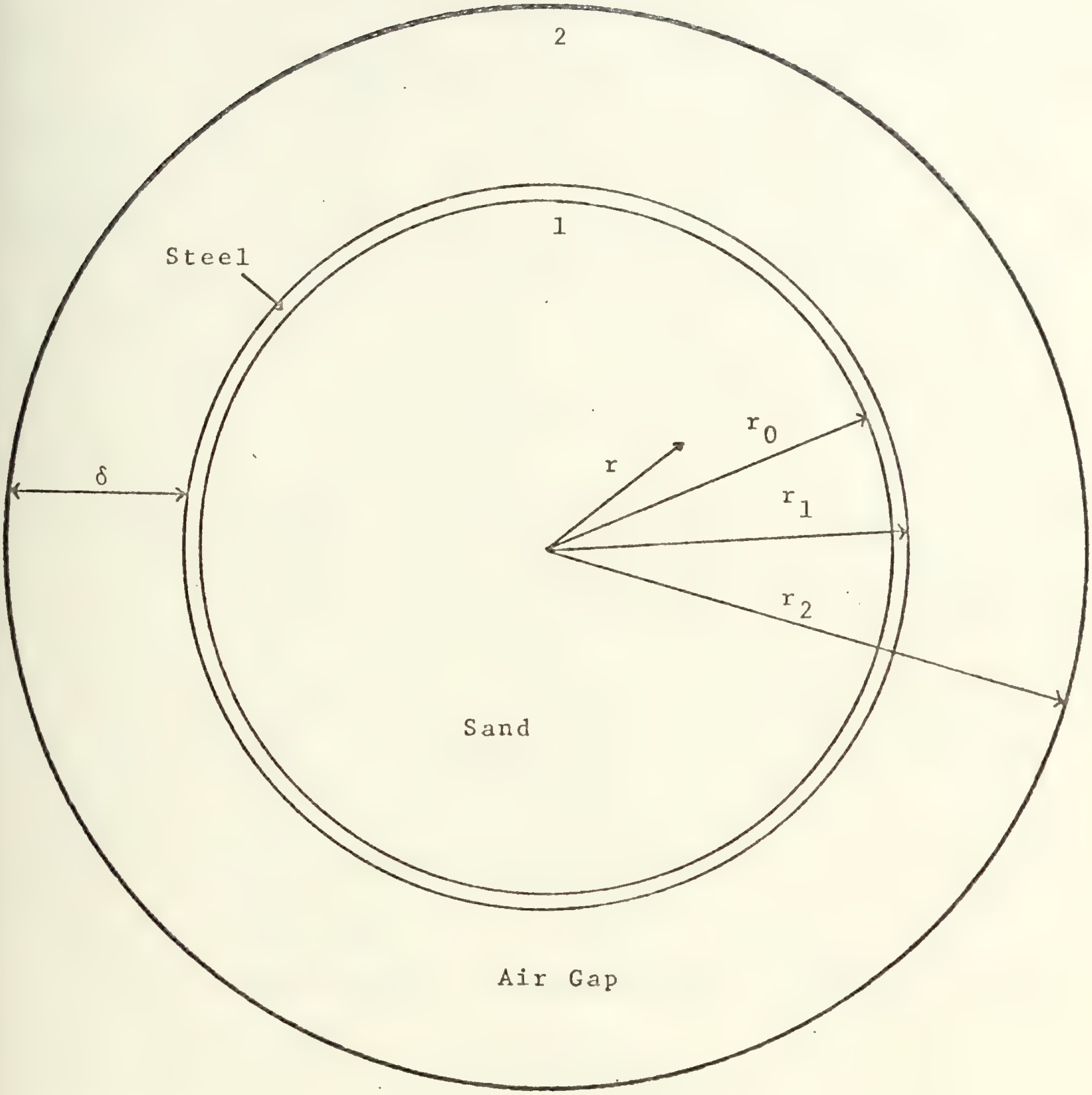

Figure 26. Analytical Model of Experimental System.

The boundary conditions used in this derivation were

$$\frac{\partial T}{\partial r} = 0 \qquad \text{at } r = 0$$

and $\frac{\partial T}{\partial r} = -\frac{\bar{h}}{k}(T - T_\infty) \qquad \text{at } r = r_0$

where r_0 is the inner radius of the rocket motor.

T_∞ is the known storage container temperature which is assumed to vary as

$$T_\infty = (T_M - T_A)\sin \omega t + T_A$$

where

T_M = maximum bulk temperature of the storage container

T_A = average bulk temperature of the storage container

ω = frequency of the sinusoidal variation $\left(\frac{2\pi}{24 \text{ hours}}\right)$

t = time

$\bar{h}$ is the effective heat transfer coefficient across the air gap between the storage container and the rocket motor. It combines the heat transfer effects of radiation, convection, and conduction into one coefficient. The radiation coefficient was linearized by assuming constant temperatures (T_1, T_2), representative of the average temperatures expected in the problem, in the equation

$$h_{RAD} = \mathcal{F}_{1-2}\sigma(T_1 + T_2)(T_1^2 + T_2^2)$$

where σ is the Stefan-Boltzmann constant and $\mathcal{F}_{1-2}$ is the radiation exchange factor between surfaces 1 and 2. The convection coefficient is

$$h_{CON} = \frac{k_c}{\delta}$$

where k_c is the effective conductivity of air as obtained from the Beckmann and Liu correlations [Ref. 5 and 7] and δ is the width of the air gap. In the analytical model,

the effective conductivity was assumed to equal the conductivity, thereby treating it as pure conduction and

$$\bar{h} = h_{RAD} + h_{CON}$$

Equation (1) was non-dimensionalized using the following relationships

$$\theta = \frac{T - T_A}{T_M - T_A} \quad \text{(a non-dimensional temperature)}$$

$$\xi = \frac{r}{r_o} \quad \text{(a non-dimensional distance)}$$

to give

$$\frac{1}{\xi} \frac{d(\xi\frac{d\theta}{d\xi})}{d\xi} = \frac{r_o^2}{\alpha} \frac{d\theta}{dt}$$

with boundary conditions

$$\frac{d\theta}{d\xi} = 0 \qquad \text{at} \quad \xi = 0$$

and $\frac{d\theta}{d\xi} = -\beta(\theta - \sin \omega t)$ at $\xi = 1$

where $\beta = \frac{\bar{h}r_o}{k}$ is the Biot modulus (which compares the relative magnitudes of the effective heat transfer coefficient across the air gap and the internal conduction resistances to heat transfer).

An initial condition was not specified as the only concern was with the steady state, periodic behavior. Following Arpaci [Ref. 1], a complex temperature was defined as

$$\psi(r,t) = \theta^*(r,t) + i\theta(r,t)$$

where $\psi(r,t)$ satisfied

$$\frac{1}{\xi} \frac{d(\xi\frac{d\psi}{d\xi})}{d\xi} = \frac{r_o^2}{\alpha} \frac{d\psi}{dt} \qquad (3)$$

with boundary conditions

$$\frac{d\psi}{d\xi} = \frac{d\theta^*}{d\xi} + i\,\frac{d\theta}{d\xi} = 0 \qquad \text{at } \xi = 0$$

and $\frac{d\psi}{d\xi} = -\beta(\psi - e^{i\omega t}) = -\beta(\theta^* - \cos\omega t) + i\{-\beta(\theta - \sin\omega t)\}$ at $\xi = 1$

This leads to $\theta(r,t)$ which satisfied

$$\frac{1}{\xi}\,\frac{d(\xi\frac{d\theta}{d\xi})}{d\xi} = \frac{r_o^2}{\alpha}\,\frac{d\theta}{dt}$$

with boundary conditions

$$\frac{d\theta}{d\xi} = 0 \qquad \text{at } \xi = 0$$

and $$\frac{d\theta}{d\xi} = -\beta(\theta - \sin\omega t) \quad \text{at } \xi = 1$$

also $\theta^*(r,t)$ which satisfied

$$\frac{1}{\xi}\,\frac{d(\xi\frac{d\theta^*}{d\xi})}{d\xi} = \frac{r_o^2}{\alpha}\,\frac{d\theta^*}{dt}$$

with boundary conditions

$$\frac{d\theta^*}{d\xi} = 0 \qquad \text{at } \xi = 0$$

and $$\frac{d\theta^*}{d\xi} = -\beta(\theta^* - \cos\omega t) \quad \text{at } \xi = 1$$

A solution of the form

$$\psi(r,t) = \phi(r)\tau(t)$$

was assumed, where for large values of time $\tau(t)$ was assumed to equal $e^{i\omega t}$; therefore,

$$\psi(r,t) = \phi(r)e^{i\omega t} \tag{4}$$

Equation (4) was then substituted into equation (3)

$$\frac{1}{\xi}\,\frac{d(\xi\frac{d\phi}{d\xi})}{d\xi} - \frac{i\omega r_o^2\phi}{\alpha} = 0 \tag{5}$$

with boundary conditions

$$\frac{d\phi}{d\xi} = 0 \qquad \text{at } \xi = 0$$

and $$\frac{d\phi}{d\xi} = -\beta(\phi-1) \qquad \text{at } \xi = 1$$

Equation (5) was expanded to give

$$\frac{d^2\phi}{d\xi^2} + \frac{1}{\xi}\frac{d\phi}{d\xi} - \frac{i\omega r_o^2}{\alpha}\phi = 0 \tag{6}$$

Now, let $Z = \sqrt{\frac{i\omega r_o^2}{\alpha}}\,\xi$

and substitute into equation (6)

$$\frac{d^2\phi}{dZ^2} + \frac{1}{Z}\frac{d\phi}{dZ} - \phi = 0 \tag{7}$$

with boundary conditions

$$\frac{d\phi}{dZ} = 0 \qquad \text{at } Z = 0$$

and

$$\frac{d\phi}{dZ} = -\frac{\beta}{\sqrt{\frac{i\omega r_o^2}{\alpha}}}(\phi-1) \quad \text{at } Z = \sqrt{\frac{i\omega r_o^2}{\alpha}}$$

The general solution of equation (7) is

$$\phi = C_1 I_o(Z) + C_2 K_o(Z) \tag{8}$$

as given in Ref. 13 with

$$I_o(Z) = 1+(\tfrac{1}{2}Z)^2 + \frac{(\frac{1}{2}Z)^4}{(2!)^2} + ---- = \sum_{n=0}^{\infty}\frac{(\frac{1}{2}Z)^{2n}}{(n!)^2}$$

and

$$K_o(Z) = -\{\gamma+\log(\tfrac{1}{2}Z)\}I_o(Z) + \sum_{n=1}^{\infty}\frac{(\frac{1}{2}Z)^{2n}}{(n!)^2}\{1 + \tfrac{1}{2} + \tfrac{1}{3} + -- \tfrac{1}{n}\}$$

Now using the boundary condition

$$\frac{d\phi}{dZ} = 0 \qquad \text{at } Z = 0$$

and differentiating equation (8) yields

$$\frac{d\phi}{dZ} = C_1 \frac{d(I_o(Z))}{dZ} + C_2 \frac{d(K_o(Z))}{dZ}$$

where

$$\frac{d(I_o(Z))}{dZ} = 0 \qquad \text{at } Z = 0$$

and

$$\frac{d(K_o(Z))}{dZ} \neq 0 \qquad \text{at } Z = 0$$

therefore $C_2 \equiv 0$

and $$\phi = C_1 \, I_o(Z) \tag{9}$$

Now using the second boundary condition that

$$\frac{d\phi}{dZ} = - \frac{\beta}{\sqrt{\frac{i\omega r_o^{\,2}}{\alpha}}} (\phi - 1) \quad \text{at } Z = \sqrt{\frac{i\omega r_o^{\,2}}{\alpha}} \tag{10}$$

and differentiating equation (9) gives

$$\frac{d\phi}{dZ} = C_1 \frac{d(I_o(Z))}{dZ}$$

Noting that $\frac{d(I_o(Z))}{dZ} = I_1(Z)$ and substituting into equation (10)

$$C_1 I_1 \left(\sqrt{\frac{i\omega r_o^{\,2}}{\alpha}}\right) = \frac{\beta}{\sqrt{\frac{i\omega r_o^{\,2}}{\alpha}}} \left(C_1 I_o \left(\sqrt{\frac{i\omega r_o^{\,2}}{\alpha}}\right) - 1\right)$$

Rearranging and solving for C_1

$$C_1 = \frac{1}{\sqrt{\frac{i\omega r_o^{\,2}}{\alpha\beta^2}} \, I_1 \left(\sqrt{\frac{i\omega r_o^{\,2}}{\alpha}}\right) + I_o \left(\sqrt{\frac{i\omega r_o^{\,2}}{\alpha}}\right)}$$

and then substituting into equation (9)

$$\phi = \frac{I_o(Z)}{I_o\left(\sqrt{\frac{i\omega r_o^2}{\alpha}}\right) + \frac{1}{\beta}\sqrt{\frac{i\omega r_o^2}{\alpha}}\; I_1\left(\sqrt{\frac{i\omega r_o^2}{\alpha}}\right)} \qquad (11)$$

Now as

$$J_\nu(imx) = i^\nu I_\nu(mx) \qquad \text{[Ref. 3, p. 135]}$$

$$I_o\left(\sqrt{\frac{\omega r_o^2}{\alpha}}\; i^{1/2}\xi\right) = J_o\left(\sqrt{\frac{\omega r_o^2}{\alpha}}\; i^{3/2}\;\xi\right)$$

and

$$I_1\left(\sqrt{\frac{\omega r_o^2}{\alpha}}\; i^{1/2}\;\xi\right) = \frac{1}{i}\; J_1\left(\sqrt{\frac{\omega r_o^2}{\alpha}}\; i^{3/2}\;\xi\right)$$

Let $a = \sqrt{\frac{\omega r_o^2}{\alpha}}$ and substitute into equation (11)

$$\phi = \frac{J_o(i^{3/2}\; a\xi)}{J_o(i^{3/2}\; a) - \frac{a}{\beta}\; i^{3/2}\; J_1(i^{3/2}\; a)} \qquad (12)$$

Now $i^{3/2} = e^{i\frac{3\pi}{4}} = \cos\frac{3\pi}{4} + i\sin\frac{3\pi}{4} = \frac{1}{\sqrt{2}}(-1 + i)$

Substituting this into equation (12)

$$\phi = \frac{J_o(i^{3/2}\; a\xi)}{J_o(i^{3/2}\; a) + \frac{a}{\sqrt{2}\beta}(1-i)J_1(i^{3/2}\; a)} \qquad (13)$$

As $J_o(a\xi i^{3/2}) = J_o(a\xi e^{i\frac{3\pi}{4}}) = BER_o(a\xi) + iBEi_o(a\xi)$

and

$$J_1(a\xi i^{3/2}) = J_1(a\xi e^{i\frac{3\pi}{4}}) = BER_1(a\xi) + iBEi_1(a\xi)$$

Substituting these results into equation (13) yields

$$\phi = \frac{BER_o(a\xi) + iBEi_o(a\xi)}{BER_o(a) + iBEi_o(a) + \frac{a}{\sqrt{2}\beta}(1-i)(BER_1(a) + iBEi_1(a))} \qquad (14)$$

After rearrangement

$$\phi = \frac{\mathrm{BER}_o(a\xi) + i\mathrm{BEi}_o(a\xi)}{[\mathrm{BER}_o(a) + \frac{a}{\sqrt{2}\beta}\mathrm{BER}_1(a) + \frac{a}{\sqrt{2}\beta}\mathrm{BEi}_1(a)] + i[\mathrm{BEi}_o(a) + \frac{a}{\sqrt{2}\beta}\mathrm{BEi}_1(a) - \frac{a}{\sqrt{2}\beta}\mathrm{BER}_1(a)]}$$

Letting

$$X_R = \mathrm{BER}_o(a) + \frac{a}{\sqrt{2}\beta}\mathrm{BER}_1(a) + \frac{a}{\sqrt{2}\beta}\mathrm{BEi}_1(a)$$

and

$$X_i = \mathrm{BEi}_o(a) + \frac{a}{\sqrt{2}\beta}\mathrm{BEi}_1(a) - \frac{a}{\sqrt{2}\beta}\mathrm{BER}_1(a)$$

and substituting into equation (14) gives

$$\phi = \frac{\mathrm{BER}_o(a\xi) + i\mathrm{BEi}_o(a\xi)}{X_R + iX_i}$$

Rationalizing the denominator yields

$$\phi = \frac{\mathrm{BER}_o(a\xi) + i\mathrm{BEi}_o(a\xi)}{X_R^2 + X_i^2}(X_R - iX_i) \qquad (15)$$

Now

$$\phi = \frac{(\mathrm{BER}_o(a\xi)X_R + \mathrm{BEi}_o(a\xi)X_i) + i(\mathrm{BEi}_o(a\xi)X_R - \mathrm{BER}_o(a\xi)X_i)}{X_R^2 + X_i^2}$$

which after rearrangement gives

$$\phi = \sqrt{\frac{\mathrm{BER}_o^2(a\xi) + \mathrm{BEi}_o^2(a\xi)}{X_R^2 + X_i^2}}\; e^{i\delta^*} \qquad (16)$$

where

$$\delta^* = \tan^{-1}\frac{\mathrm{BEi}_o(a\xi)X_R - \mathrm{BER}_o(a\xi)X_i}{\mathrm{BER}_o(a\xi)X_R + \mathrm{BEi}_o(a\xi)X_i}$$

Substituting into equation (4) gives

$$\psi(r,t) = \sqrt{\frac{BER_o^2(a\xi) + BEi_o^2(a\xi)}{X_R^2 + X_i^2}}\ e^{i(\omega t + \delta^*)}$$

which also equals

$$\psi(r,t) = \sqrt{\frac{BER_o^2(a\xi) + BEi_o^2(a\xi)}{X_R^2 + X_i^2}}\ [\cos(\omega t+\delta^*) + i \sin(\omega t+\delta^*)]$$

As this problem was modeled as a sine wave, the imaginary part of $\psi(r,t)$ was used.

$$I(\psi(r,t)) = \theta(r,t) = \sqrt{\frac{BER_o^2(a\xi) + BEi_o^2(a\xi)}{X_R^2 + X_i^2}}\ \sin(\omega t+\delta^*) \quad (17)$$

which is the analytical solution of infinitely long concentric cylinders experiencing a periodic sinusoidal temperature variation on its outermost surface when heat conduction is assumed to be radial only.

In summary

$$\theta(r,t) = \frac{T-T_A}{T_M-T_A} = \sqrt{\frac{BER_o^2(a\xi) + BEi_o^2(a\xi)}{X_R^2 + X_i^2}}\ \sin(\omega t+ \delta^*)$$

where

T = the temperature of a point r in the rocket motor at time t

T_A = average bulk temperature of the storage container

T_M = maximum bulk temperature of the storage container

ω = frequency of the sinusoidal variation ($2\pi/24$ hours)

t = time

$\xi = \frac{r}{r_o}$ = dimensionless distance from the center of the rocket motor

r_o = distance to the surface of the rocket motor

r = distance from the center of the rocket motor

$a = \sqrt{\frac{\omega r_o^2}{\alpha}}$ = conduction parameter

$$\alpha = \frac{k}{\rho c} = \text{thermal diffusivity}$$

ρ = density
k = thermal conductivity
c = specific heat
BER = real Bessel Function
BEi = imaginary Bessel Function

$$X_R = \mathrm{BER}_o(a) + \frac{a}{\sqrt{2}\beta}\,\mathrm{BER}_1(a) + \frac{a}{\sqrt{2}\beta}\,\mathrm{BEi}_1(a)$$

$$X_i = \mathrm{BEi}_o(a) + \frac{a}{\sqrt{2}\beta}\,\mathrm{BEi}_1(a) - \frac{a}{\sqrt{2}\beta}\,\mathrm{BER}_1(a)$$

$$\beta = \frac{\bar{h}r_o}{k} = \text{Biot modulus}$$

$$\delta^* = \tan^{-1}\frac{\mathrm{BEi}_o(a\xi)X_R - \mathrm{BER}_o(a\xi)X_i}{\mathrm{BER}_o(a\xi)X_R + \mathrm{BEi}_o(a\xi)X_i}$$

The following computer programs were used to investigate a wide variety of parameters. The outputs are samples of some of these parameter studies.

ANALYTICAL SOLUTION PARAMETER STUDY

```
      DO 2 K=1,5
      READ(5,11)A
   11 FORMAT(F10.6)
      WRITE(6,31)
   31 FORMAT(' ',19X,'A',4X,'B',4X,'DISTANCE FROM CENTER',4X,'TIME DELAY
     1 IN RADIANS',3X,'RELATIVE AMPLITUDE')
      DO 3 L=1,10
      READ(5,11)B
C FROM INPUT VALUES OF A AND B, CALCULATE THE DENOMINATOR(DENOM) OF EQUATION 17.
      Y=SQRT(2.0)
      Z=A
      BEROZ=(1.0-(Z**4/64.0)+(Z**8/147500.0))
      BEIOZ=0.25*Z**2*(1.0-(Z**4/576.0)+(Z**8/3790000.0))
      BER1Z=-Z/(2.0*Y)*(1.0+(Z**2/8.0)-(Z**4/128.0)-(Z**6/9216.0)+(Z**8/
     1737280.0))
      BEI1Z=Z/(2.0*Y)*(1.0-(Z**2/8.0)-(Z**4/128.0)+(Z**6/9216.0)+(Z**8/7
     137280.0))
      XR=BEROZ+A/(Y*B)*BER1Z+A/(Y*B)*BEI1Z
      XI=BEIOZ+A/(Y*B)*BEI1Z-A/(Y*B)*BER1Z
      V=XR**2+XI**2
      DENOM=SQRT(V)
C AT THE CENTER, HALF WAY TO THE SURFACE,AND AT THE SURFACE OF THE MOTOR,
C CALCULATE THE NUMERATOR(DNUM) OF EQUATION 17.
      DO 30 I=1,3
      C=(I-1)/2.0
      Z=A*C
      BEROZ=(1.0-(Z**4/64.0)+(Z**8/147500.0))
      BEIOZ=0.25*Z**2*(1.0-(Z**4/576.0)+(Z**8/3790000.0))
      U=BEROZ**2+BEIOZ**2
      DNUM=SQRT(U)
C CALCULATE THE TIME DELAY(DEL).
      DNU=XR*BEIOZ-XI*BEROZ
      DNO=XR*BEROZ+XI*BEIOZ
      X=DNU/DNO
      IF(DNO.LT.0.0)GO TO 22
      DEL=ATAN(X)
      GO TO 23
   22 DEL=ATAN(X)-3.14159
C CALCULATE THE RELATIVE AMPLITUDE(S).
   23 S=DNUM/DENOM
      WRITE(6,32)A,B,C,DEL,S
   32 FORMAT(' ',18X,F3.1,1X,F5.1,12X,F3.1,19X,F5.2,18X,F4.2)
   30 CONTINUE
    3 CONTINUE
    2 CONTINUE
      STOP
      END
```

A	B	DISTANCE FROM CENTER	TIME DELAY IN RADIANS	RELATIVE AMPLITUDE
1.0	0.1	0.0	-1.50	0.19
1.0	0.1	0.5	-1.44	0.19
1.0	0.1	1.0	-1.25	0.19
1.0	0.5	0.0	-0.97	0.66
1.0	0.5	0.5	-0.90	0.66
1.0	0.5	1.0	-0.72	0.67
1.0	1.0	0.0	-0.68	0.84
1.0	1.0	0.5	-0.62	0.84
1.0	1.0	1.0	-0.43	0.86
1.0	2.0	0.0	-0.48	0.93
1.0	2.0	0.5	-0.42	0.93
1.0	2.0	1.0	-0.23	0.94
1.0	3.0	0.0	-0.41	0.95
1.0	3.0	0.5	-0.34	0.95
1.0	3.0	1.0	-0.16	0.97
1.0	4.0	0.0	-0.37	0.96
1.0	4.0	0.5	-0.31	0.96
1.0	4.0	1.0	-0.12	0.98
1.0	5.0	0.0	-0.34	0.97
1.0	5.0	0.5	-0.28	0.97
1.0	5.0	1.0	-0.10	0.98
1.0	10.0	0.0	-0.30	0.98
1.0	10.0	0.5	-0.23	0.98
1.0	10.0	1.0	-0.05	0.99
1.0	50.0	0.0	-0.26	0.98
1.0	50.0	0.5	-0.20	0.98
1.0	50.0	1.0	-0.01	1.00
1.0	100.0	0.0	-0.25	0.98
1.0	100.0	0.5	-0.19	0.99
1.0	100.0	1.0	-0.00	1.00

```
  A     B    DISTANCE FROM CENTER   TIME DELAY IN RADIANS   RELATIVE AMPLITUDE

 2.0   0.1          0.0                   -2.03                   0.05
 2.0   0.1          0.5                   -1.78                   0.05
 2.0   0.1          1.0                   -1.12                   0.06
 2.0   0.5          0.0                   -1.84                   0.22
 2.0   0.5          0.5                   -1.59                   0.22
 2.0   0.5          1.0                   -0.92                   0.27
 2.0   1.0          0.0                   -1.66                   0.37
 2.0   1.0          0.5                   -1.41                   0.37
 2.0   1.0          1.0                   -0.74                   0.45
 2.0   2.0          0.0                   -1.43                   0.54
 2.0   2.0          0.5                   -1.18                   0.54
 2.0   2.0          1.0                   -0.52                   0.66
 2.0   3.0          0.0                   -1.31                   0.62
 2.0   3.0          0.5                   -1.06                   0.63
 2.0   3.0          1.0                   -0.39                   0.76
 2.0   4.0          0.0                   -1.23                   0.67
 2.0   4.0          0.5                   -0.98                   0.68
 2.0   4.0          1.0                   -0.31                   0.82
 2.0   5.0          0.0                   -1.17                   0.70
 2.0   5.0          0.5                   -0.93                   0.71
 2.0   5.0          1.0                   -0.26                   0.86
 2.0  10.0          0.0                   -1.05                   0.76
 2.0  10.0          0.5                   -0.81                   0.77
 2.0  10.0          1.0                   -0.14                   0.93
 2.0  50.0          0.0                   -0.94                   0.80
 2.0  50.0          0.5                   -0.69                   0.82
 2.0  50.0          1.0                   -0.03                   0.99
 2.0 100.0          0.0                   -0.93                   0.81
 2.0 100.0          0.5                   -0.68                   0.82
 2.0 100.0          1.0                   -0.01                   0.99
```

A	B	DISTANCE FROM CENTER	TIME DELAY IN RADIANS	RELATIVE AMPLITUDE
3.0	0.1	0.0	-2.76	0.02
3.0	0.1	0.5	-2.22	0.02
3.0	0.1	1.0	-1.08	0.04
3.0	0.5	0.0	-2.64	0.09
3.0	0.5	0.5	-2.09	0.10
3.0	0.5	1.0	-0.95	0.18
3.0	1.0	0.0	-2.51	0.16
3.0	1.0	0.5	-1.96	0.18
3.0	1.0	1.0	-0.82	0.32
3.0	2.0	0.0	-2.32	0.26
3.0	2.0	0.5	-1.77	0.28
3.0	2.0	1.0	-0.63	0.51
3.0	3.0	0.0	-2.19	0.33
3.0	3.0	0.5	-1.65	0.35
3.0	3.0	1.0	-0.51	0.63
3.0	4.0	0.0	-2.11	0.36
3.0	4.0	0.5	-1.56	0.39
3.0	4.0	1.0	-0.42	0.71
3.0	5.0	0.0	-2.04	0.39
3.0	5.0	0.5	-1.50	0.42
3.0	5.0	1.0	-0.36	0.76
3.0	10.0	0.0	-1.89	0.45
3.0	10.0	0.5	-1.34	0.49
3.0	10.0	1.0	-0.20	0.88
3.0	50.0	0.0	-1.73	0.50
3.0	50.0	0.5	-1.19	0.54
3.0	50.0	1.0	-0.04	0.98
3.0	100.0	0.0	-1.71	0.51
3.0	100.0	0.5	-1.16	0.55
3.0	100.0	1.0	-0.02	0.99

```
  A     B    DISTANCE FROM CENTER    TIME DELAY IN RADIANS   RELATIVE AMPLITUDE
 4.0   0.1          0.0                     -3.65                  0.01
 4.0   0.1          0.5                     -2.74                  0.01
 4.0   0.1          1.0                     -1.24                  0.02
 4.0   0.5          0.0                     -3.56                  0.03
 4.0   0.5          0.5                     -2.65                  0.04
 4.0   0.5          1.0                     -1.15                  0.11
 4.0   1.0          0.0                     -3.46                  0.06
 4.0   1.0          0.5                     -2.55                  0.08
 4.0   1.0          1.0                     -1.05                  0.22
 4.0   2.0          0.0                     -3.29                  0.11
 4.0   2.0          0.5                     -2.38                  0.14
 4.0   2.0          1.0                     -0.88                  0.39
 4.0   3.0          0.0                     -3.16                  0.15
 4.0   3.0          0.5                     -2.25                  0.18
 4.0   3.0          1.0                     -0.75                  0.51
 4.0   4.0          0.0                     -3.06                  0.18
 4.0   4.0          0.5                     -2.15                  0.22
 4.0   4.0          1.0                     -0.65                  0.60
 4.0   5.0          0.0                     -2.98                  0.20
 4.0   5.0          0.5                     -2.07                  0.24
 4.0   5.0          1.0                     -0.57                  0.67
 4.0  10.0          0.0                     -2.75                  0.24
 4.0  10.0          0.5                     -1.84                  0.30
 4.0  10.0          1.0                     -0.34                  0.84
 4.0  50.0          0.0                     -2.49                  0.28
 4.0  50.0          0.5                     -1.58                  0.35
 4.0  50.0          1.0                     -0.08                  0.97
 4.0 100.0          0.0                     -2.45                  0.29
 4.0 100.0          0.5                     -1.54                  0.35
 4.0 100.0          1.0                     -0.04                  0.99
```

```
 A     B    DISTANCE FROM CENTER    TIME DELAY IN RADIANS   RELATIVE AMPLITUDE

5.0   0.1           0.0                     -4.30                  0.00
5.0   0.1           0.5                     -2.99                  0.00
5.0   0.1           1.0                     -1.17                  0.01
5.0   0.5           0.0                     -4.25                  0.01
5.0   0.5           0.5                     -2.95                  0.02
5.0   0.5           1.0                     -1.13                  0.07
5.0   1.0           0.0                     -4.19                  0.02
5.0   1.0           0.5                     -2.89                  0.03
5.0   1.0           1.0                     -1.07                  0.13
5.0   2.0           0.0                     -4.09                  0.04
5.0   2.0           0.5                     -2.78                  0.06
5.0   2.0           1.0                     -0.96                  0.24
5.0   3.0           0.0                     -4.00                  0.05
5.0   3.0           0.5                     -2.69                  0.08
5.0   3.0           1.0                     -0.87                  0.33
5.0   4.0           0.0                     -3.92                  0.07
5.0   4.0           0.5                     -2.61                  0.10
5.0   4.0           1.0                     -0.79                  0.41
5.0   5.0           0.0                     -3.85                  0.08
5.0   5.0           0.5                     -2.55                  0.12
5.0   5.0           1.0                     -0.72                  0.48
5.0  10.0           0.0                     -3.62                  0.11
5.0  10.0           0.5                     -2.32                  0.17
5.0  10.0           1.0                     -0.49                  0.69
5.0  50.0           0.0                     -3.25                  0.15
5.0  50.0           0.5                     -1.95                  0.23
5.0  50.0           1.0                     -0.13                  0.94
5.0 100.0           0.0                     -3.19                  0.16
5.0 100.0           0.5                     -1.89                  0.24
5.0 100.0           1.0                     -0.07                  0.97
```

ANALYTICAL SOLUTION - SAMPLE PROBLEM

```
//WIR11687 JOB (1687,0860FT,NF12),'WIRZBURGER,ALLEN'
// EXEC FORTCLGP,REGION=150K
//FORT.SYSIN DD *
          REAL LABEL
          REAL*8 ITITLE(12)
          REAL*4 J2
INPUT VALUES ARE A, B, MAXIMUM TEMPERATURE AND AVERAGE TEMPERATURE.
          DIMENSION J2(49),TINF(49),T(7,49),T1(49),T2(49)
          READ(5,11)A,B,TM,TA
     11   FORMAT(4F10.6)
          READ(5,10) (ITITLE(I), I=1, 12)
     10   FORMAT(6A8)
          DMEGA=2.0*3.14159/1440.0
FROM INPUT VALUES OF A AND B, CALCULATE THE DENOMINATOR(DENOM) OF EQUATION 17.
          Y=SQRT(2.0)
          Z=A
          BEROZ=(1.0-(Z**4/64.0)+(Z**8/147500.0))
          BEIOZ=0.25*Z**2*(1.0-(Z**4/576.0)+(Z**8/3790000.0))
          BER1Z=-Z/(2.0*Y)*(1.0+(Z**2/8.0)-(Z**4/123.0)-(Z**6/9216.0)+(Z**8/
         1737280.0))
          BEI1Z=Z/(2.0*Y)*(1.0-(Z**2/8.0)-(Z**4/128.0)+(Z**6/9216.0)+(Z**8/7
         137280.0))
          XR=BEROZ+A/(Y*B)*BER1Z+A/(Y*B)*BEI1Z
          XI=BEIOZ+A/(Y*B)*BEI1Z-A/(Y*B)*BER1Z
          V=XR**2+XI**2
          DENOM=SQRT(V)
          N=0
THE TEMPERATURE OF THE CONTAINER(TINF) IS CALCULATED AT 30 MINUTE INTERVALS.
          DO 40 J=1,1441,30
          N=N+1
          J2(N)=J-1
          TEMP=DMEGA*J2(N)
          TINF(N)=(TM-TA)*SIN(TEMP)+TA
          IF(J.EQ.1441) GO TO 31
          L=(N-1)/6
          N2=N-1
          L2=6*L
          IF(N2.EQ.L2) GO TO 21
FOR SEVEN POSITIONS BETWEEN THE CENTER OF THE ROCKET MOTOR AND THE SURFACE, THE
NUMERATOR(DNUM) OF EQUATION 17 AND THE TIME DELAY(DEL) ARE CALCULATED.
     32   DO 30 I=1,7
          C=(I-1)/5.75
          IF(C.GT.1.0) C=1.0
          Z=A*C
          BEROZ=(1.0-(Z**4/64.0)+(Z**8/147500.0))
          BEIOZ=0.25*Z**2*(1.0-(Z**4/576.0)+(Z**8/3790000.0))
```

```
      U=BEROZ**2+BEIOZ**2
      DNUM=SQRT(U)
      DNU=XR*BEIOZ-XI*BEROZ
      DNO=XR*BEROZ+XI*BEIOZ
      X=DNU/DNO
      IF(DNO.LT.0.0)GO TO 22
      DEL=ATAN(X)
      GO TO 23
   22 DEL=ATAN(X)-3.14159
   23 TIME=DMEGA*J2(N)+DEL
      THETA=DNUM/DENOM*SIN(TIME)
C THE TEMPERATURE AT EACH POSITION IS CALCULATED.
      T(I,N)=THETA*(TM-TA)+TA
      C=I-1
      IF(C.EQ.6.0) C=5.75
      DEL=DEL/DMEGA
      WRITE(6,50)C,J2(N),T(I,N),TINF(N),DEL
   50 FORMAT(' ',26X,F4.2,10X,F6.1,5X,F6.2,14X,F6.2,13X,F7.2)
      T1(N)=T(1,N)
      T2(N)=T(7,N)
      IF((I.EQ.1).AND.(J.EQ.1441)) GO TO 33
      IF((I.EQ.7).AND.(J.EQ.1441)) GO TO 34
   30 CONTINUE
   40 CONTINUE
      STOP
C A TEMPERATURE VERSUS TIME GRAPH IS DRAWN SHOWING THE TEMPERATURE OF THE STORAGE
C CONTAINER(TINF), THE TEMPERATURE OF THE SURFACE OF THE ROCKET MOTOR(TEDG) AND
C THE TEMPERATURE AT THE CENTER OF THE MOTOR(TCEN).
   31 READ(5,9) LABEL
    9 FORMAT(A4)
      CALL DRAW(49,J2,TINF,1,0,LABEL,ITITLE,0,0,0,0,0,0,9,15,1,LAST)
      GO TO 32
   33 READ(5,9) LABEL
      CALL DRAW(49,J2,T1,2,0,LABEL,ITITLE,0,0,0,0,0,0,9,15,1,LAST)
      GO TO 30
   34 READ(5,9) LABEL
      CALL DRAW(49,J2,T2,3,0,LABEL,ITITLE,0,0,0,0,0,0,9,15,1,LAST)
      GO TO 30
   21 WRITE(6,7)
    7 FORMAT('1',//////////////)
      WRITE(6,20)
   20 FORMAT(' ',19X,'DISTANCE FROM CENTER',3X,'TIME',3X,'TEMPERATURE',2
     1X,'TEMPERATURE OF CONTAINER',3X,'TIME DELAY')
      WRITE(6,60)
   60 FORMAT('+',19X,'________ ____ ______',3X,'____',3X,'___________',2
     1X,'___________ __ _________',3X,'____ _____',/)
      GO TO 32
      END
```

```
DISTANCE FROM CENTER   TIME   TEMPERATURE  TEMPERATURE OF CONTAINER   TIME DELAY
       0.0              0.0      88.28            104.00               -388.40
       1.00             0.0      88.20            104.00               -378.17
       2.00             0.0      88.06            104.00               -347.61
       3.00             0.0      88.13            104.00               -297.89
       4.00             0.0      88.90            104.00               -232.81
       5.00             0.0      91.02            104.00               -159.10
       5.75             0.0      94.00            104.00               -102.29
       0.0             30.0      88.16            108.44               -388.40
       1.00            30.0      88.17            108.44               -378.17
       2.00            30.0      88.30            108.44               -347.61
       3.00            30.0      88.84            108.44               -297.89
       4.00            30.0      90.25            108.44               -232.81
       5.00            30.0      93.17            108.44               -159.10
       5.75            30.0      96.81            108.44               -102.29
       0.0             60.0      88.31            112.80               -388.40
       1.00            60.0      88.41            112.80               -378.17
       2.00            60.0      88.82            112.80               -347.61
       3.00            60.0      89.81            112.80               -297.89
       4.00            60.0      91.84            112.80               -232.81
       5.00            60.0      95.50            112.80               -159.10
       5.75            60.0      99.75            112.80               -102.29
       0.0             90.0      88.73            117.01               -388.40
       1.00            90.0      88.92            117.01               -378.17
       2.00            90.0      89.60            117.01               -347.61
       3.00            90.0      91.03            117.01               -297.89
       4.00            90.0      93.63            117.01               -232.81
       5.00            90.0      97.98            117.01               -159.10
       5.75            90.0     102.76            117.01               -102.29
       0.0            120.0      89.41            121.00               -388.40
       1.00           120.0      89.69            121.00               -378.17
       2.00           120.0      90.62            121.00               -347.61
       3.00           120.0      92.46            121.00               -297.89
       4.00           120.0      95.60            121.00               -232.81
       5.00           120.0     100.56            121.00               -159.10
       5.75           120.0     105.79            121.00               -102.29
       0.0            150.0      90.34            124.70               -388.40
       1.00           150.0      90.70            124.70               -378.17
       2.00           150.0      91.88            124.70               -347.61
       3.00           150.0      94.09            124.70               -297.89
       4.00           150.0      97.72            124.70               -232.81
       5.00           150.0     103.20            124.70               -159.10
       5.75           150.0     108.79            124.70               -102.29
```

DISTANCE FROM CENTER	TIME	TEMPERATURE	TEMPERATURE OF CONTAINER	TIME DELAY
0.0	180.0	91.50	128.04	-388.40
1.00	180.0	91.94	128.04	-378.17
2.00	180.0	93.34	128.04	-347.61
3.00	180.0	95.90	128.04	-297.89
4.00	180.0	99.94	128.04	-232.81
5.00	180.0	105.85	128.04	-159.10
5.75	180.0	111.71	128.04	-102.29
0.0	210.0	92.88	130.97	-388.40
1.00	210.0	93.39	130.97	-378.17
2.00	210.0	94.98	130.97	-347.61
3.00	210.0	97.84	130.97	-297.89
4.00	210.0	102.23	130.97	-232.81
5.00	210.0	108.47	130.97	-159.10
5.75	210.0	114.49	130.97	-102.29
0.0	240.0	94.44	133.44	-388.40
1.00	240.0	95.01	133.44	-378.17
2.00	240.0	96.77	133.44	-347.61
3.00	240.0	99.88	133.44	-297.89
4.00	240.0	104.56	133.44	-232.81
5.00	240.0	111.01	133.44	-159.10
5.75	240.0	117.10	133.44	-102.29
0.0	270.0	96.18	135.41	-388.40
1.00	270.0	96.79	135.41	-378.17
2.00	270.0	98.70	135.41	-347.61
3.00	270.0	102.00	135.41	-297.89
4.00	270.0	106.87	135.41	-232.81
5.00	270.0	113.44	135.41	-159.10
5.75	270.0	119.48	135.41	-102.29
0.0	300.0	98.04	136.84	-388.40
1.00	300.0	98.70	136.84	-378.17
2.00	300.0	100.71	136.84	-347.61
3.00	300.0	104.15	136.84	-297.89
4.00	300.0	109.13	136.84	-232.81
5.00	300.0	115.70	136.84	-159.10
5.75	300.0	121.60	136.84	-102.29
0.0	330.0	100.01	137.71	-388.40
1.00	330.0	100.69	137.71	-378.17
2.00	330.0	102.77	137.71	-347.61
3.00	330.0	106.30	137.71	-297.89
4.00	330.0	111.31	137.71	-232.81
5.00	330.0	117.76	137.71	-159.10
5.75	330.0	123.42	137.71	-102.29

```
DISTANCE FROM CENTER   TIME   TEMPERATURE   TEMPERATURE OF CONTAINER   TIME DELAY

      0.0             360.0     102.04             138.00               -388.40
      1.00            360.0     102.74             138.00               -378.17
      2.00            360.0     104.86             138.00               -347.61
      3.00            360.0     108.41             138.00               -297.89
      4.00            360.0     113.36             138.00               -232.81
      5.00            360.0     119.59             138.00               -159.10
      5.75            360.0     124.90             138.00               -102.29
      0.0             390.0     104.11             137.71               -388.40
      1.00            390.0     104.82             137.71               -378.17
      2.00            390.0     106.94             137.71               -347.61
      3.00            390.0     110.44             137.71               -297.89
      4.00            390.0     115.25             137.71               -232.81
      5.00            390.0     121.15             137.71               -159.10
      5.75            390.0     126.03             137.71               -102.29
      0.0             420.0     106.18             136.84               -388.40
      1.00            420.0     106.88             136.84               -378.17
      2.00            420.0     108.96             136.84               -347.61
      3.00            420.0     112.37             136.84               -297.89
      4.00            420.0     116.95             136.84               -232.81
      5.00            420.0     122.42             136.84               -159.10
      5.75            420.0     126.78             136.84               -102.29
      0.0             450.0     108.21             135.41               -388.40
      1.00            450.0     108.89             135.41               -378.17
      2.00            450.0     110.90             135.41               -347.61
      3.00            450.0     114.15             135.41               -297.89
      4.00            450.0     118.43             135.41               -232.81
      5.00            450.0     123.37             135.41               -159.10
      5.75            450.0     127.14             135.41               -102.29
      0.0             480.0     110.16             133.44               -388.40
      1.00            480.0     110.81             133.44               -378.17
      2.00            480.0     112.72             133.44               -347.61
      3.00            480.0     115.75             133.44               -297.89
      4.00            480.0     119.66             133.44               -232.81
      5.00            480.0     123.99             133.44               -159.10
      5.75            480.0     127.10             133.44               -102.29
      0.0             510.0     112.02             130.97               -388.40
      1.00            510.0     112.62             130.97               -378.17
      2.00            510.0     114.39             130.97               -347.61
      3.00            510.0     117.16             130.97               -297.89
      4.00            510.0     120.62             130.97               -232.81
      5.00            510.0     124.27             130.97               -159.10
      5.75            510.0     126.67             130.97               -102.29
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DISTANCE FROM CENTER     TIME      TEMPERATURE    TEMPERATURE OF CONTAINER    TIME DELAY

        0.0              540.0       113.73               128.04               -388.40
        1.00             540.0       114.28               128.04               -378.17
        2.00             540.0       115.88               128.04               -347.61
        3.00             540.0       118.34               128.04               -297.89
        4.00             540.0       121.30               128.04               -232.81
        5.00             540.0       124.20               128.04               -159.10
        5.75             540.0       125.85               128.04               -102.29
        0.0              570.0       115.28               124.70               -388.40
        1.00             570.0       115.77               124.70               -378.17
        2.00             570.0       117.17               124.70               -347.61
        3.00             570.0       119.27               124.70               -297.89
        4.00             570.0       121.68               124.70               -232.81
        5.00             570.0       123.78               124.70               -159.10
        5.75             570.0       124.66               124.70               -102.29
        0.0              600.0       116.64               121.00               -388.40
        1.00             600.0       117.06               121.00               -378.17
        2.00             600.0       118.24               121.00               -347.61
        3.00             600.0       119.95               121.00               -297.89
        4.00             600.0       121.76               121.00               -232.81
        5.00             600.0       123.03               121.00               -159.10
        5.75             600.0       123.11               121.00               -102.29
        0.0              630.0       117.77               117.01               -388.40
        1.00             630.0       118.12               117.01               -378.17
        2.00             630.0       119.06               117.01               -347.61
        3.00             630.0       120.35               117.01               -297.89
        4.00             630.0       121.53               117.01               -232.81
        5.00             630.0       121.95               117.01               -159.10
        5.75             630.0       121.24               117.01               -102.29
        0.0              660.0       118.68               112.80               -388.40
        1.00             660.0       118.94               112.80               -378.17
        2.00             660.0       119.62               112.80               -347.61
        3.00             660.0       120.47               112.80               -297.89
        4.00             660.0       121.01               112.80               -232.81
        5.00             660.0       120.57               112.80               -159.10
        5.75             660.0       119.07               112.80               -102.29
        0.0              690.0       119.33               108.44               -388.40
        1.00             690.0       119.50               108.44               -378.17
        2.00             690.0       119.92               108.44               -347.61
        3.00             690.0       120.31               108.44               -297.89
        4.00             690.0       120.19               108.44               -232.81
        5.00             690.0       118.90               108.44               -159.10
        5.75             690.0       116.64               108.44               -102.29
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DISTANCE FROM CENTER   TIME   TEMPERATURE  TEMPERATURE OF CONTAINER   TIME DELAY

        0.0            720.0    119.72             104.00              -388.40
        1.00           720.0    119.80             104.00              -378.17
        2.00           720.0    119.94             104.00              -347.61
        3.00           720.0    119.87             104.00              -297.89
        4.00           720.0    119.10             104.00              -232.81
        5.00           720.0    116.98             104.00              -159.10
        5.75           720.0    114.00             104.00              -102.29
        0.0            750.0    119.84              99.56              -388.40
        1.00           750.0    119.83              99.56              -378.17
        2.00           750.0    119.70              99.56              -347.61
        3.00           750.0    119.16              99.56              -297.89
        4.00           750.0    117.75              99.56              -232.81
        5.00           750.0    114.83              99.56              -159.10
        5.75           750.0    111.19              99.56              -102.29
        0.0            780.0    119.69              95.20              -388.40
        1.00           780.0    119.59              95.20              -378.17
        2.00           780.0    119.18              95.20              -347.61
        3.00           780.0    118.19              95.20              -297.89
        4.00           780.0    116.16              95.20              -232.81
        5.00           780.0    112.50              95.20              -159.10
        5.75           780.0    108.25              95.20              -102.29
        0.0            810.0    119.27              90.99              -388.40
        1.00           810.0    119.08              90.99              -378.17
        2.00           810.0    118.40              90.99              -347.61
        3.00           810.0    116.97              90.99              -297.89
        4.00           810.0    114.37              90.99              -232.81
        5.00           810.0    110.02              90.99              -159.10
        5.75           810.0    105.24              90.99              -102.29
        0.0            840.0    118.59              87.00              -388.40
        1.00           840.0    118.31              87.00              -378.17
        2.00           840.0    117.38              87.00              -347.61
        3.00           840.0    115.54              87.00              -297.89
        4.00           840.0    112.40              87.00              -232.81
        5.00           840.0    107.44              87.00              -159.10
        5.75           840.0    102.21              87.00              -102.29
        0.0            870.0    117.66              83.30              -388.40
        1.00           870.0    117.30              83.30              -378.17
        2.00           870.0    116.12              83.30              -347.61
        3.00           870.0    113.91              83.30              -297.89
        4.00           870.0    110.28              83.30              -232.81
        5.00           870.0    104.81              83.30              -159.10
        5.75           870.0     99.21              83.30              -102.29
```

```
DISTANCE FROM CENTER    TIME    TEMPERATURE  TEMPERATURE OF CONTAINER    TIME DELAY
        0.0             900.0     116.50              79.96               -388.40
        1.00            900.0     116.06              79.96               -378.17
        2.00            900.0     114.66              79.96               -347.61
        3.00            900.0     112.10              79.96               -297.89
        4.00            900.0     108.06              79.96               -232.81
        5.00            900.0     102.15              79.96               -159.10
        5.75            900.0      96.29              79.96               -102.29
        0.0             930.0     115.12              77.03               -388.40
        1.00            930.0     114.61              77.03               -378.17
        2.00            930.0     113.02              77.03               -347.61
        3.00            930.0     110.16              77.03               -297.89
        4.00            930.0     105.77              77.03               -232.81
        5.00            930.0      99.53              77.03               -159.10
        5.75            930.0      93.51              77.03               -102.29
        0.0             960.0     113.56              74.56               -388.40
        1.00            960.0     112.99              74.56               -378.17
        2.00            960.0     111.23              74.56               -347.61
        3.00            960.0     108.12              74.56               -297.89
        4.00            960.0     103.44              74.56               -232.81
        5.00            960.0      96.99              74.56               -159.10
        5.75            960.0      90.90              74.56               -102.29
        0.0             990.0     111.83              72.59               -388.40
        1.00            990.0     111.21              72.59               -378.17
        2.00            990.0     109.30              72.59               -347.61
        3.00            990.0     106.00              72.59               -297.89
        4.00            990.0     101.13              72.59               -232.81
        5.00            990.0      94.56              72.59               -159.10
        5.75            990.0      88.52              72.59               -102.29
        0.0            1020.0     109.96              71.16               -388.40
        1.00           1020.0     109.30              71.16               -378.17
        2.00           1020.0     107.29              71.16               -347.61
        3.00           1020.0     103.85              71.16               -297.89
        4.00           1020.0      98.87              71.16               -232.81
        5.00           1020.0      92.30              71.16               -159.10
        5.75           1020.0      86.40              71.16               -102.29
        0.0            1050.0     107.99              70.29               -388.40
        1.00           1050.0     107.31              70.29               -378.17
        2.00           1050.0     105.23              70.29               -347.61
        3.00           1050.0     101.70              70.29               -297.89
        4.00           1050.0      96.69              70.29               -232.81
        5.00           1050.0      90.24              70.29               -159.10
        5.75           1050.0      84.58              70.29               -102.29
```

```
DISTANCE FROM CENTER   TIME   TEMPERATURE  TEMPERATURE OF CONTAINER   TIME DELAY

       0.0           1080.0     105.96             70.00               -388.40
       1.00          1080.0     105.26             70.00               -378.17
       2.00          1080.0     103.14             70.00               -347.61
       3.00          1080.0      99.59             70.00               -297.89
       4.00          1080.0      94.64             70.00               -232.81
       5.00          1080.0      88.41             70.00               -159.10
       5.75          1080.0      83.10             70.00               -102.29
       0.0           1110.0     103.89             70.29               -388.40
       1.00          1110.0     103.18             70.29               -378.17
       2.00          1110.0     101.06             70.29               -347.61
       3.00          1110.0      97.56             70.29               -297.89
       4.00          1110.0      92.75             70.29               -232.81
       5.00          1110.0      86.85             70.29               -159.10
       5.75          1110.0      81.97             70.29               -102.29
       0.0           1140.0     101.82             71.16               -388.40
       1.00          1140.0     101.12             71.16               -378.17
       2.00          1140.0      99.04             71.16               -347.61
       3.00          1140.0      95.63             71.16               -297.89
       4.00          1140.0      91.05             71.16               -232.81
       5.00          1140.0      85.58             71.16               -159.10
       5.75          1140.0      81.22             71.16               -102.29
       0.0           1170.0      99.79             72.59               -388.40
       1.00          1170.0      99.11             72.59               -378.17
       2.00          1170.0      97.10             72.59               -347.61
       3.00          1170.0      93.85             72.59               -297.89
       4.00          1170.0      89.57             72.59               -232.81
       5.00          1170.0      84.63             72.59               -159.10
       5.75          1170.0      80.86             72.59               -102.29
       0.0           1200.0      97.84             74.56               -388.40
       1.00          1200.0      97.19             74.56               -378.17
       2.00          1200.0      95.28             74.56               -347.61
       3.00          1200.0      92.25             74.56               -297.89
       4.00          1200.0      88.34             74.56               -232.81
       5.00          1200.0      84.01             74.56               -159.10
       5.75          1200.0      80.90             74.56               -102.29
       0.0           1230.0      95.98             77.03               -388.40
       1.00          1230.0      95.38             77.03               -378.17
       2.00          1230.0      93.61             77.03               -347.61
       3.00          1230.0      90.84             77.03               -297.89
       4.00          1230.0      87.38             77.03               -232.81
       5.00          1230.0      83.73             77.03               -159.10
       5.75          1230.0      81.33             77.03               -102.29
```

```
DISTANCE FROM CENTER     TIME    TEMPERATURE  TEMPERATURE OF CONTAINER    TIME DELAY

       0.0              1260.0      94.27              79.96               -388.40
       1.00             1260.0      93.72              79.96               -378.17
       2.00             1260.0      92.12              79.96               -347.61
       3.00             1260.0      89.66              79.96               -297.89
       4.00             1260.0      86.70              79.96               -232.81
       5.00             1260.0      83.60              79.96               -159.10
       5.75             1260.0      82.15              79.96               -102.29
       0.0              1290.0      92.72              83.30               -388.40
       1.00             1290.0      92.23              83.30               -378.17
       2.00             1290.0      90.83              83.30               -347.61
       3.00             1290.0      88.73              83.30               -297.89
       4.00             1290.0      86.32              83.30               -232.81
       5.00             1290.0      84.22              83.30               -159.10
       5.75             1290.0      83.34              83.30               -102.29
       0.0              1320.0      91.36              87.00               -388.40
       1.00             1320.0      90.94              87.00               -378.17
       2.00             1320.0      89.76              87.00               -347.61
       3.00             1320.0      88.05              87.00               -297.89
       4.00             1320.0      86.24              87.00               -232.81
       5.00             1320.0      84.97              87.00               -159.10
       5.75             1320.0      84.89              87.00               -102.29
       0.0              1350.0      90.23              90.99               -388.40
       1.00             1350.0      89.88              90.99               -378.17
       2.00             1350.0      88.94              90.99               -347.61
       3.00             1350.0      87.65              90.99               -297.89
       4.00             1350.0      86.47              90.99               -232.81
       5.00             1350.0      86.05              90.99               -159.10
       5.75             1350.0      86.76              90.99               -102.29
       0.0              1380.0      89.32              95.20               -388.40
       1.00             1380.0      89.06              95.20               -378.17
       2.00             1380.0      88.38              95.20               -347.61
       3.00             1380.0      87.53              95.20               -297.89
       4.00             1380.0      86.99              95.20               -232.81
       5.00             1380.0      87.43              95.20               -159.10
       5.75             1380.0      88.93              95.20               -102.29
       0.0              1410.0      88.67              99.56               -388.40
       1.00             1410.0      88.50              99.56               -378.17
       2.00             1410.0      88.08              99.56               -347.61
       3.00             1410.0      87.69              99.56               -297.89
       4.00             1410.0      87.81              99.56               -232.81
       5.00             1410.0      89.10              99.56               -159.10
       5.75             1410.0      91.36              99.56               -102.29
```

APPENDIX C

TRUMP Solution

TRUMP is a computer program for solving transient and steady-state temperature distributions in multidimensional systems. This program was developed in 1965 at the Lawrence Radiation Laboratory by A. L. Edwards [Ref. 2] for their CDC/3600 computer. The program was adapted to the Naval Postgraduate School IBM/360 Model 67 computer system in 1971 by C. Erbayrum [Ref. 3] from a version used by the B. F. Goodrich Corporation.

TRUMP is a multipurpose program able to solve a wide variety of problems involving flow in various kinds of potential fields such as heat flow in a temperature field. TRUMP allows the solution of general nonlinear parabolic partial differential equations both in steady-state and transient problems. Complex geometric configurations with multidimensional flow may be solved using various coordinate systems. Initial conditions may vary with spatial position. Material properties, boundary conditions, and other problem parameters may vary with spatial position, time, or the primary dependent variable.

Input data are fed to TRUMP in "Block" form through its 12 input data blocks. A complete description of each of these blocks is given in Ref. 2. A model of the problem must be constructed and data from this model read into TRUMP through the data blocks.

Two models were used to simulate the rocket motor storage container system and several variations of each model were investigated.

The first model assumed one dimensional heat transfer (radial) with the assumptions that the system was infinitely long and that the container surface temperature was spatially uniform. The system was modeled as two infinitely long concentric cylinders separated by a 2.94 inch air gap. The inner cylinder was constructed of 4130 steel and was filled with dry wind blown sand. The thermal properties of the materials used in the experimental system are given in Table II with units most easily compared to the actual data obtained from the system at China Lake.

TABLE II
Thermal Properties of Materials

Material	Density	Specific Heat	Thermal Conductivity
Sand	0.05486lbm/in^3	0.195BTU/lbm°F	0.00026BTU/min-in-°F
Steel	0.2807 lbm/in^3	0.109BTU/lbm°F	0.364 BTU/min-in-°F
Air	0.0000436 "	0.240BTU/lbm°F	0.0000225 "

The model was subdivided into volume elements or nodes with the representative nodal points given in Figure 27. Although the representative nodal point may be located anywhere in the node or on the surface of the node, in transient problems it is usually located so that the lines connecting the nodal points are perpendicularly bisected by the connected area. This gives maximum accuracy. Two boundary conditions were given to the surface node. The first was a sinusoidal disturbance which closely modeled the actual

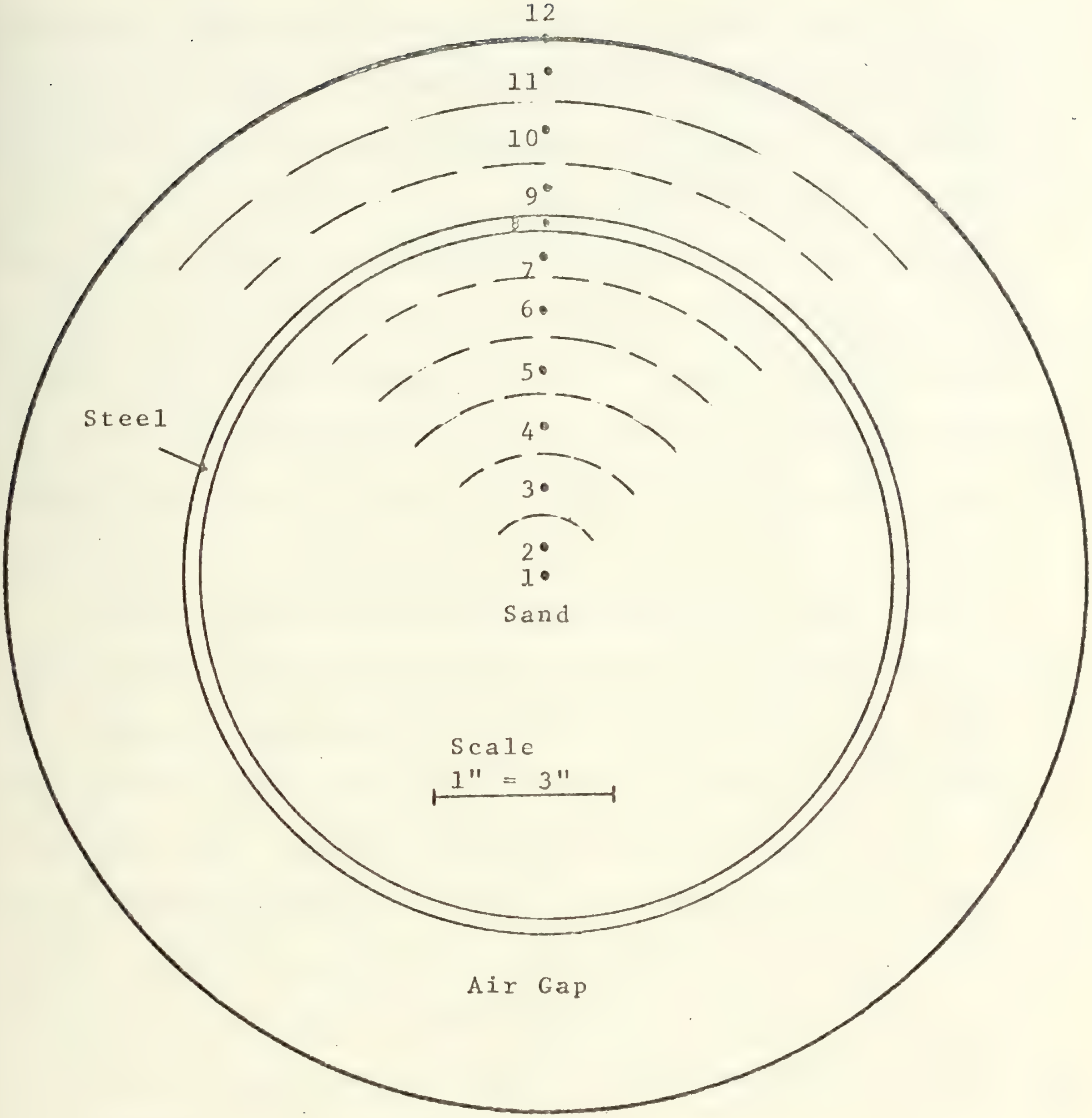

Figure 27. Location of Nodes for One Dimensional TRUMP Model.

average experimental data obtained at China Lake as given in Appendix D. The sine wave exhibited a maximum temperature of 138°F and an average temperature of 104°F. Its period was 24 hours (1440 minutes). The second boundary condition was the actual average surface temperature of the storage container given at two hour intervals. Both these boundary conditions are approximations of the actual surface temperature. Two hour intervals were the minimum allowable for the tabular data as this version of TRUMP has a maximum table size of 12.

Several assumptions were initially made. The thermocouple data obtained from the experiment at China Lake gave the average temperature at a point on the storage container and not the actual outside surface temperature. As this container wall was only 1/16 of an inch thick and made of a good thermal conductor, it was decided to model this data as a zero volume boundary node with a known temperature impressed on it. It was also assumed that heat transfer across the air gap occurred only by radiation and conduction, neglecting the effects of free convection.

It was estimated that the surface emissivities for the rocket motor and the storage container were 0.9 [Ref. 6] based on their haze gray surfaces. The radiation exchange factor for this geometry is given by

$$\mathcal{F}_{1-2} = \frac{1}{\frac{1}{\varepsilon_1} + \frac{r_1}{r_2}\left(\frac{1}{\varepsilon_2} - 1\right)} = 0.84$$

A sample input deck for the tabular approximation of the boundary condition is given at the end of this appendix. Several cycles of output data for the one dimensional model are also given.

The second model assumed two dimensional heat transfer (radial and circumferential) with the assumption that the system was infinitely long. The same physical model was assumed for the system except 48 nodes were used instead of 12. The representative nodal points are given in Figure 28. The four surface nodes (12, 24, 36, and 48) each had two different temperature approximations applied, a sinusoidal representation and a tabular input taken at two hour intervals. The four surface nodes were also modeled as zero volume boundary nodes. Each internal thermal connection between nodes is described in the input data by specifying the two node identification numbers, two connector lengths, and two interface dimensional factors. An example of the thermal connections of node 4 is shown in Figure 28 and the input data in BLOCK 5 of the two dimensional TRUMP program.

The calculation of the radiosities in the two dimensional case was accomplished by using a radiation-network and the method of crossed-strings.

The radiation shape factors for the two dimensional system were determined by the method of crossed-strings [Ref. 14]. The graphical construction for this method is given in Figure 29.

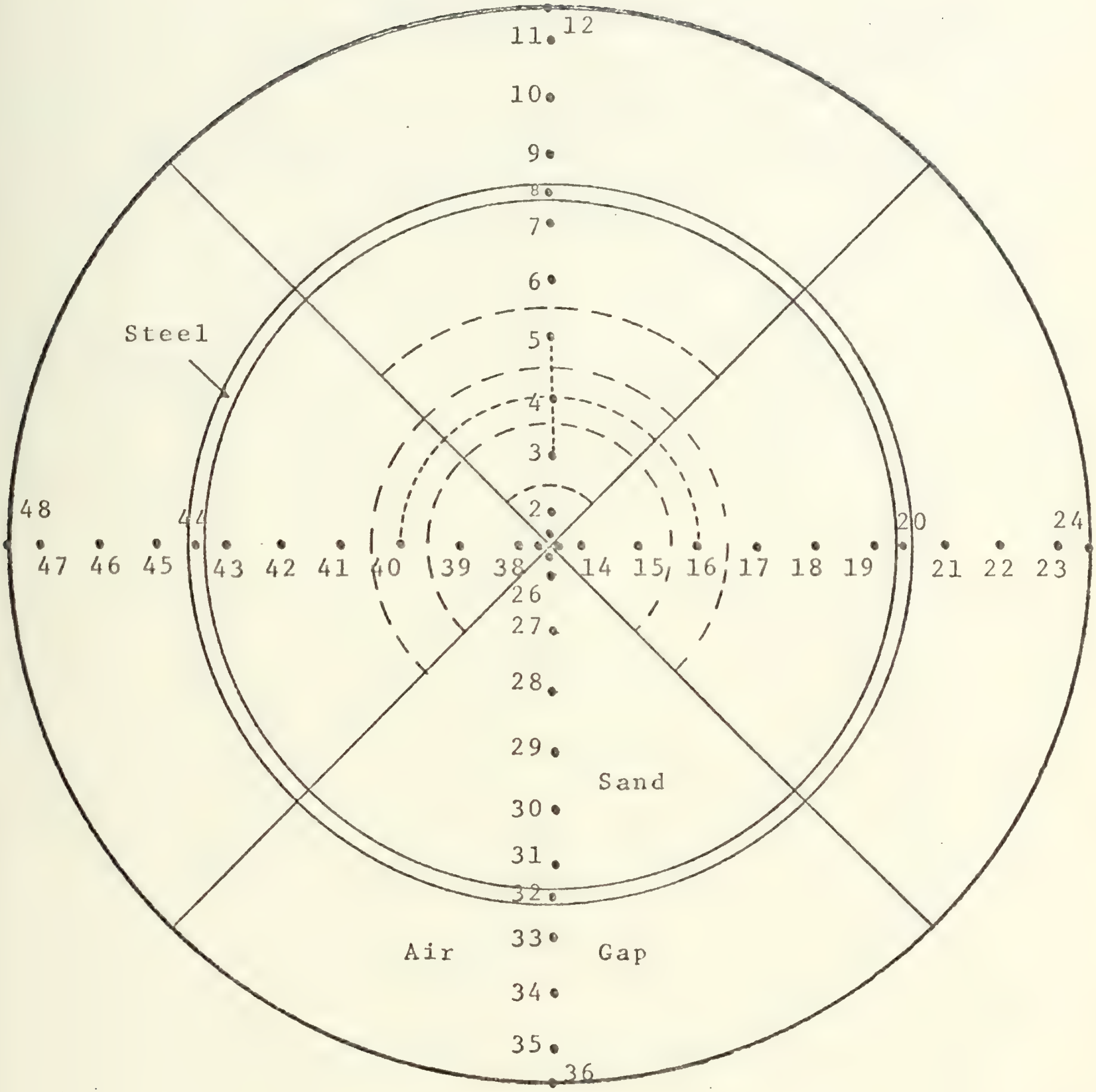

Figure 28: Location of Nodes for Two Dimensional TRUMP Model.

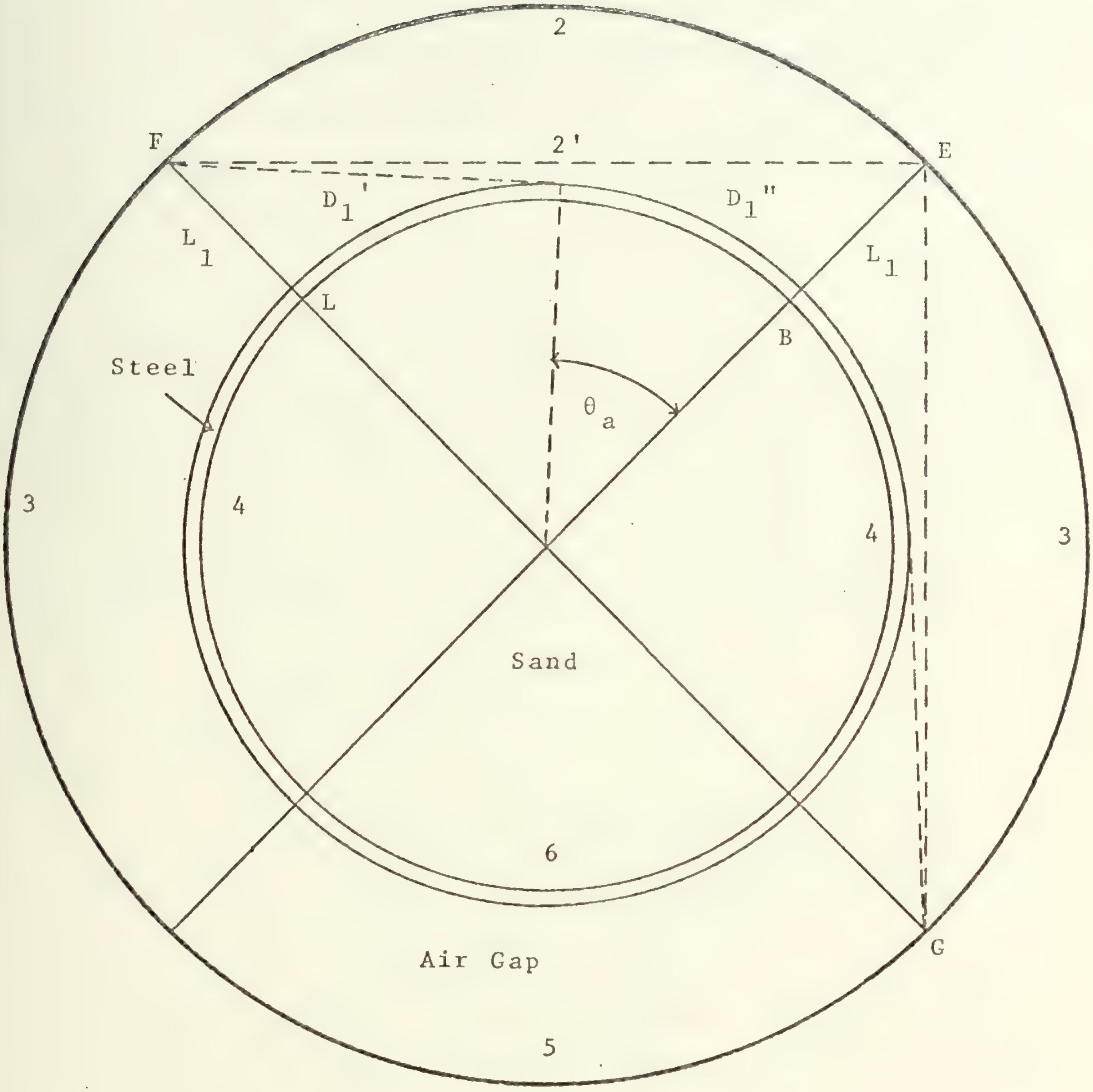

Figure 29: Graphical Construction for Crossed-Strings Method.

F_{m-n} is defined as the fraction of energy leaving surface m which directly reaches surface n. From the physical dimensions of the model $A_1 = A_4 = A_6 = 9.45 \frac{\text{sq.in}}{\text{in.}}$, $A_2 = A_3 = A_5 = 14.05 \frac{\text{sq.in}}{\text{in}}$, $A_{2'} = 12.65 \frac{\text{sq.in}}{\text{in}}$, assuming unit depth. Let S_i equal the length of A_i.

The crossed-string method lets each surface represent the effective surface obtained by stretching a string tightly over the radiating face between the bounding edges, to produce a surface that cannot see any of itself. For example, surface 2' in Figure 29 stretched over surface 2. By definition $F_{2'2} \equiv 1$, which by reciprocity leads to

$$F_{22'} = \frac{A_{2'}}{A_2} F_{2'2} = 0.9$$

and therefore since

$$F_{22} + F_{22'} = 1 \quad \text{then } F_{22} = 0.10$$

To calculate the direct radiant heat exchanged between surfaces 1 and 2, a minimum-length line was stretched connecting edge B of A_1 to edge E of A_2 and a second minimum length line from edge L of A_1 to edge F of A_2. These lines are labeled L_1 in Figure 29 and are equal to the width of the air gap, $L_1 = 2.9375$ in. Minimum length lines were also stretched from point B on A_1 to F on A_2 and L on A_1 to E on A_2. The length of these lines is D_1 and is made up of two parts; D_1', the tangential distance from F to surface A_1 and D_1'', the arc length from the point the tangent hits A_1 to B. From geometry $D_1' = \sqrt{r_1^2 - r_o^2} = 6.62''$

$$D_1'' = r_o\,\theta_a = 4.42''$$

therefore

$$D_1 = D_1' + D_1'' = 11.04''$$

Now $F_{12} = \dfrac{2D_1 - 2L_1}{2S_1} = 0.86$

From reciprocity, $A_1 F_{12} = A_2 F_{21}$

$$F_{21} = \frac{r_o}{r_1} F_{12} = 0.578$$

Now F_{13} is calculated from

$$F_{12} + 2F_{13} = 1$$

therefore $F_{13} = 0.07$

From symmetry $F_{42} = F_{13}$

and then by reciprocity

$$F_{24} = \frac{r_o}{r_1} F_{42} = 0.047$$

Now F_{23} was calculated by stretching minimum length lines from F to E, from E to G, from F to G and from E to E; where the length of the line from F to E = from E to G = S_2', from F to G = $2D_1$, and from E to E = 0

$$F_{23} = \frac{2S_2' - 2D_1}{2S_2} = .113$$

F_{25} was now calculated from

$$F_{21} + F_{22} + F_{23} + F_{24} + F_{25} = 1$$

therefore $F_{25} = 0.002$

As F_{25} was much smaller than the other F_{m-n}, it was not included in the radiation-network diagram in Figure 30 [Ref. 15].

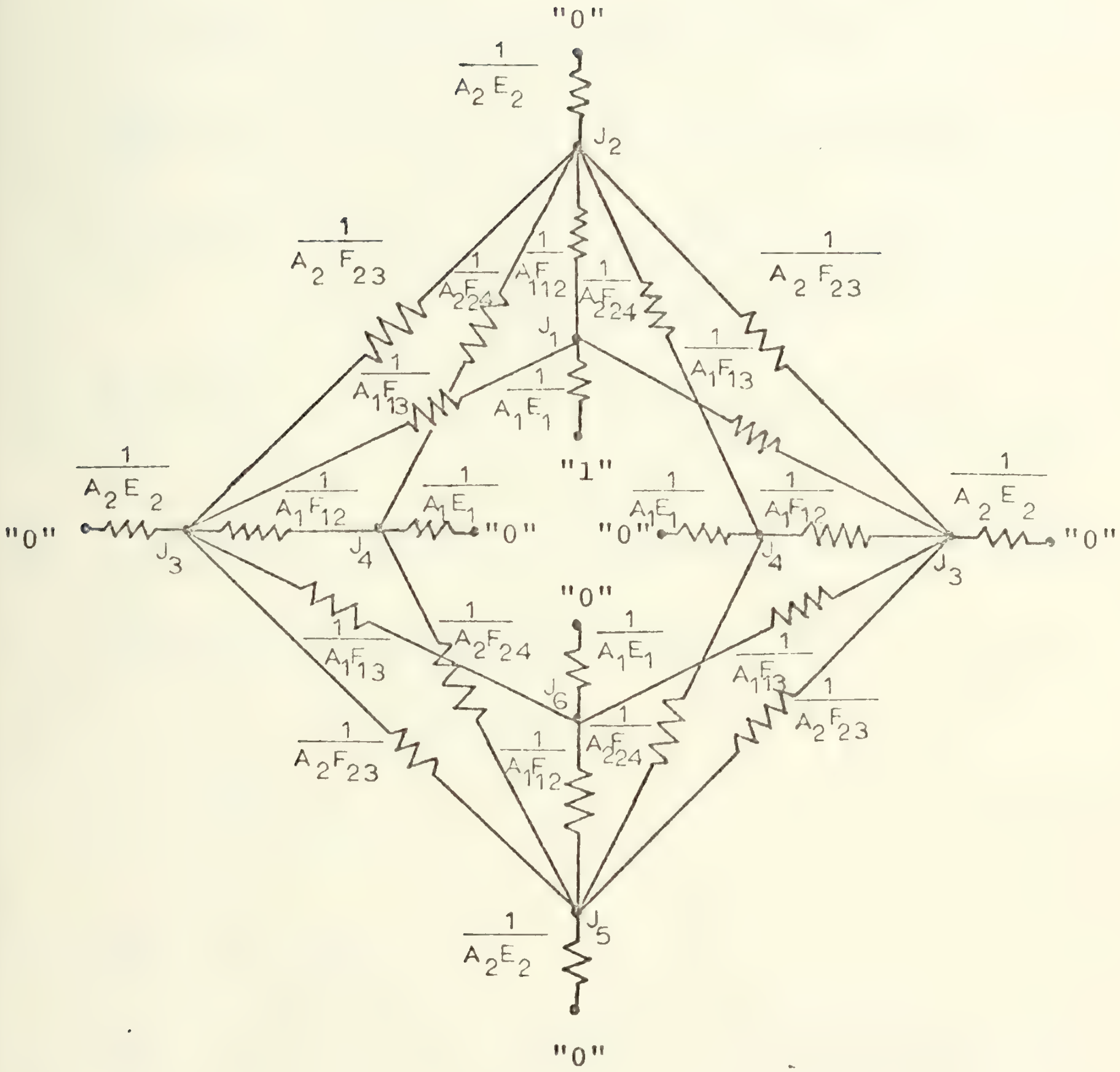

Figure 30: Radiation Network.

To calculate F_{1-n}, the blackbody potential of area 1 is set to unity and all other blackbody potentials are set as zero. An energy balance was written at each node giving a set of six simultaneous equations as follows:

Node 1

$$E_1A_1(1-J_1) = A_1F_{12}(J_1-J_2)+ 2A_1F_{13}(J_1-J_3)$$

Node 2

$$E_2A_2(0-J_2) = A_1F_{12}(J_2-J_1)+ 2A_2F_{24}(J_2-J_4)+ 2A_2F_{23}(J_2-J_3)$$

Node 3

$$E_2A_2(0-J_3) = A_1F_{12}(J_3-J_4)+ A_2F_{23}(J_3-J_2)+ A_1F_{13}(J_3-J_1)+ A_1F_{13}(J_3-J_6)+ A_2F_{23}(J_3-J_5)$$

Node 4

$$E_1A_1(0-J_4) = A_2F_{24}(J_4-J_2)+ A_1F_{12}(J_4-J_3)+ A_2F_{24}(J_4-J_5)$$

Node 5

$$E_2A_2(0-J_5) = 2A_2F_{23}(J_5-J_3)+2A_2F_{24}(J_5-J_4)+A_1F_{12}(J_5-J_6)$$

Node 6

$$E_1A_1(0-J_6) = 2A_1F_{13}(J_6-J_3)+ A_1F_{12}(J_6-J_5)$$

where J_n = radiosity of node n

$$E_1A_1 = \frac{\varepsilon_1}{1-\varepsilon_1} A_1$$

$$E_2A_2 = \frac{\varepsilon_2}{1-\varepsilon_2} A_2$$

F_{nm} = radiation shape factors previously calculated.

Now the values of A_1, A_2 and F_{nm} were substituted into the energy balance equations which were then put into matrix form as shown in Table III.

TABLE III

Matrix Form of Energy Balance Equations

$$\begin{bmatrix} (\frac{1}{1-\varepsilon_1}) & (-0.86) & (-0.14) & (0.0) & (0.0) & (0.0) \\ (-0.86) & (1.33+\frac{3\varepsilon_2}{2(1-\varepsilon_2)}) & (-0.33) & (-0.14) & (0.0) & (0.0) \\ (-0.07) & (-0.165) & (1.33+\frac{3\varepsilon_2}{2(1-\varepsilon_2)}) & (-0.86) & (-0.165) & (-0.07) \\ (0.0) & (-0.07) & (-0.86) & (\frac{1}{1-\varepsilon_1}) & (-0.07) & (0.0) \\ (0.0) & (0.0) & (-0.14) & (0.0) & (-0.86) & (\frac{1}{1-\varepsilon_1}) \\ (0.0) & (0.0) & (-0.33) & (-0.14) & (1.33+\frac{3\varepsilon_2}{2(1-\varepsilon_2)}) & (-0.86) \end{bmatrix} \begin{bmatrix} J_1 \\ J_2 \\ J_3 \\ J_4 \\ J_5 \\ J_6 \end{bmatrix} = \begin{bmatrix} (\frac{\varepsilon_1}{1-\varepsilon_1}) \\ (0.0) \\ (0.0) \\ (0.0) \\ (0.0) \\ (0.0) \end{bmatrix}$$

Letting $\varepsilon_1 = \varepsilon_2 = 0.9$, a standard computer solution for matrix problems gave the radiosities as listed in Table IV.

TABLE IV

Radiosities at Nodes

$J_1 = .9046$
$J_2 = .0529$
$J_3 = .00495$
$J_4 = .000797$
$J_5 = .000125$
$J_6 = .000080$

Now to find the radiation exchange factors from node 1 to nodes n, the radiation network shown in Figure 30 was reduced to the equivalent network shown in Figure 31. Where the nodal equations are

$$\mathcal{F}_{1-2}\, A_1(1-0) = E_2 A_2 (J_2 - 0)$$

where

$$\mathcal{F}_{1-2} = \frac{E_2\ A_2}{A_1} J_2 = .71$$

$$\mathcal{F}_{13} A_1 (1-0) = E_2 A_2 (J_3 - 0)$$

$$\mathcal{F}_{1-3} = \frac{E_2\ A_2}{A_1} J_3 = .066$$

These values of the radiation exchange factor are used in the two-dimensional program. A sample input deck for the sinusoidal boundary condition is included at the end of this appendix. Several cycles of output data for the tabular boundary condition are also given.

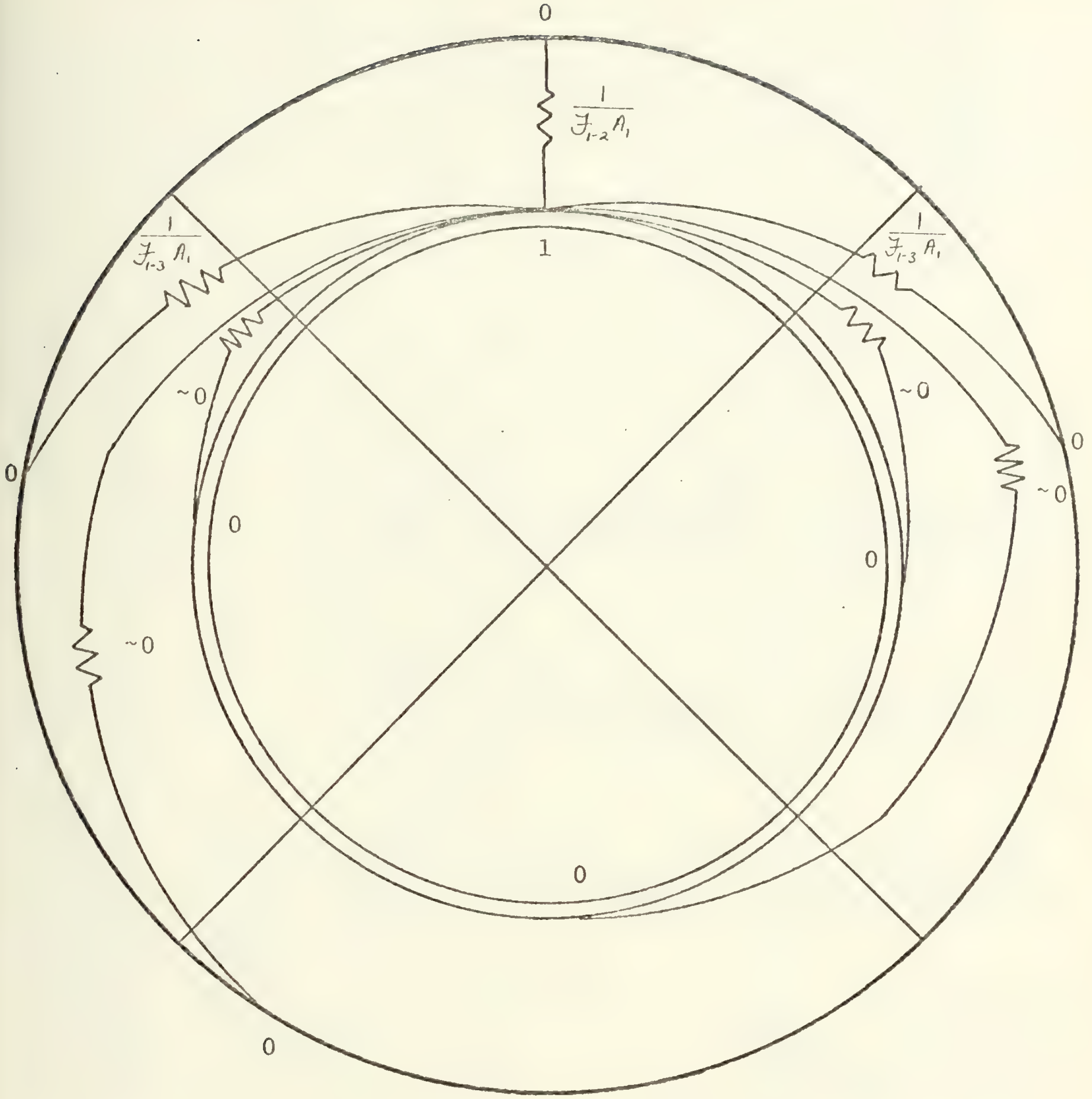
0
$\frac{1}{\mathcal{F}_{1-2}A_1}$
$\frac{1}{\mathcal{F}_{1-3}A_1}$
$\frac{1}{\mathcal{F}_{1-3}A_1}$
1
~0
~0
0
0
~0
0
0
~0
0
0
0

Figure 31: Equivalent Radiation Network

```
//WIR31687 JOB (1687,0860FT,NF12),'WIRZBURGER.A. BOX W',TIME=(2,00)
//JOBLIB       DD   UNIT=2321,DSNAME=S1734.KATZ,
//    DISP=(OLD,PASS),VOLUME=SER=CEL001
//  EXEC    PGM=TRUMP,REGION=350K
//FT06F001     DD   SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=3325),
//     SPACE=(CYL,(6,1))
//FT05F001     DD   *

*   MISSLE PROBLEM    ONE DIMENSIONAL

BLOCK 1   CONTROLS, LIMITS, CONSTANTS
    1        1
    2    3         1.000 E 00 1.000E 00           1440.0
 93.0

BLOCK 2     MATERIAL NAMES, NUMBERS, THERMAL PROPERTIES.
ASAND    1                     0.0544     0.19      0.00027
ASTEL    2                     0.2807     0.109     0.0364
AAIR     3                     0.0000436  0.240     0.0000225

BLOCK 4   NODE NUMBERS, MATERIAL REFERENCES, TYPES, VOLUMES.
    1              1            1.0        0.002     0.001
    2              1            1.0        0.998     0.501
    3              1            1.0        1.0       1.5
    4              1            1.0        1.0       2.5
    5              1            1.0        1.0       3.5
    6              1            1.0        1.0       4.5
    7              1            1.0        0.75      5.375
    8              2            1.0        0.25      5.875
    9              3            1.0        1.0       6.5
   10              3            1.0        1.0       7.5
   11              3            1.0        0.9375    8.46875
   12              2            0.0        0.0       8.9375

BLOCK 5   INTERNAL THERMAL CONNECTION NODE NUMBERS.
    1    2          0.001      0.499      1.0       0.002
    2    3          0.499      0.5        1.0       1.0
    3    4          0.5        0.5        1.0       2.0
    4    5          0.5        0.5        1.0       3.0
    5    6          0.5        0.5        1.0       4.0
    6    7          0.5        0.375      1.0       5.0
    7    8          0.3750     0.125      1.0       5.75
    8    9          0.1250     0.5        1.0       6.0
    8   12          0.125      0.0        1.0       6.0                  0.00009760
    9   10          0.5        0.5        1.0       7.0
   10   11          0.500      0.46875    1.0       8.0
   11   12          0.46875    0.0        1.0       8.9375
```

```
BLOCK 6   EXTERNAL THERMAL CONNECTIONS
   12 2001                     1.0       8.9375    1.00   E6

BLOCK 7    BOUNDARY TEMPERATURE VARIATION.
 2001   12           89.5      120.0     84.5      240.0      79.25      360.0
  76.0     480.0     69.75     600.0     82.25     720.0     103.75     840.0
 119.0     960.0    130.0     1080.0    138.0     1200.0     132.25    1320.0
 103.5    1440.0

BLOCK 9   INITIAL TEMPERATURES
    1                115.2
    2                115.3
    3                116.0
    4                117.2
    5                118.4
    6                118.7
    7                117.3
    8                115.8
    9                113.2
   10                108.9
   11                105.1
   12                103.5

ENDED-1     LAST CARD OF DATA DECK
```

```
MISSLE PROBLEM    ONE DIMENSIONAL
   INPUT UNIT =   5.  OUTPUT UNIT =     6.
===============================================================================================
DATA BLOCK  10                 CONTROLS, LIMITS, CONSTANTS

IPRINT   NUM KDATA KSPEC  MCYC  MSEC NPUNCH NDOT IRITE                      SCALE
   15      0     1     0 30000 30000     0     0     0                    0.10000E 01

  KD   KT     DELTO        SMALL        TVARY        TAU          TIMAX        TMIN         TMAX
   2    3  1.00000E 12  1.00000E 00  1.00000E 00  0.0          1.44000E 03 -1.00000E 12  1.00000E 12

   KD KSYM     GEOM        SIGMA        TBASE
    2    1  6.28319D 00  1.73000E-09  4.60000E 02

   TONE        ALONE        BONE         GONE         FONE         HONE         RONE         PONE
  9.3000E 01  0.0          0.0          0.0          0.0          0.0          0.0          0.0
===============================================================================================
DATA BLOCK  20                 MATERIAL NAMES, NUMBERS, THERMAL PROPERTIES.

NAME MATL INDEX  KA  KB LTABC LTABK    DENSITY      CAPACITY   CONDUCTIVITY   TMELT         HMELT
 SAND   1    1    0   0    0     0    5.4400E-02   1.9000E-01   2.7000E-04   0.0           0.0
 STEL   2    2    0   0    0     0    2.8070E-01   1.0900E-01   3.6400E-02   0.0           0.0
 AIR    3    3    0   0    0     0    4.3600E-05   2.4000E-01   2.2500E-05   0.0           0.0
===============================================================================================
DATA BLOCK  40                 NODE NUMBERS, MATERIAL REFERENCES, TYPES, VOLUMES.

  NODE  INDEX MATL NTYPE,     DLONG          DWIDE          DRAD           VOLUME
     1     1     1     0   1.00000E 00    2.00000E-03    1.00000E-03    1.25664E-05
     2     2     1     0   1.00000E 00    9.98000E-01    5.01000E-01    3.14158E 00
     3     3     1     0   1.00000E 00    1.00000E 00    1.50000E 00    9.42478E 00
     4     4     1     0   1.00000E 00    1.00000E 00    2.50000E 00    1.57080E 01
     5     5     1     0   1.00000E 00    1.00000E 00    3.50000E 00    2.19911E 01
     6     6     1     0   1.00000E 00    1.00000E 00    4.50000E 00    2.82743E 01
     7     7     1     0   1.00000E 00    7.50000E-01    5.37500E 00    2.53291E 01
     8     8     2     0   1.00000E 00    2.50000E-01    5.87500E 00    9.22843E 00
     9     9     3     0   1.00000E 00    1.00000E 00    6.50000E 00    4.08407E 01
    10    10     3     0   1.00000E 00    1.00000E 00    7.50000E 00    4.71239E 01
    11    11     3     0   1.00000E 00    9.37500E-01    8.46875E 00    4.98850E 01
    12    12     2     2   0.0            0.0            8.93750E 00    1.00000E-24
===============================================================================================
DATA BLOCK  50                 INTERNAL THERMAL CONNECTION NODE NUMBERS.

 NOD1 NOD2 INDEX  DEL1         DEL2         DLONG        DRAD         HINT         RINT          AREA
    1    2    1  1.0000D-03   4.9900D-01   1.0000E 00   2.0000E-03   1.0000E 12   0.0          1.2566D-02
    2    3    2  4.9900D-01   5.0000D-01   1.0000E 00   1.0000E 00   1.0000E 12   0.0          6.2832D 00
    3    4    3  5.0000D-01   5.0000D-01   1.0000E 00   2.0000E 00   1.0000E 12   0.0          1.2566D 01
    4    5    4  5.0000D-01   5.0000D-01   1.0000E 00   3.0000E 00   1.0000E 12   0.0          1.8850D 01
    5    6    5  5.0000D-01   5.0000D-01   1.0000E 00   4.0000E 00   1.0000E 12   0.0          2.5133D 01
    6    7    6  5.0000D-01   3.7500D-01   1.0000E 00   5.0000E 00   1.0000E 12   0.0          3.1416D 01
    7    8    7  3.7500D-01   1.2500D-01   1.0000E 00   5.7500E 00   1.0000E 12   0.0          3.6128D 01
    8    9    8  1.2500D-01   5.0000D-01   1.0000E 00   6.0000E 00   1.0000E 12   0.0          3.7699D 01
    8   12    9  1.2500D-01   0.0          1.0000E 00   6.0000E 00   1.0000E-24   9.7600E-05   3.7699D 01
    9   10   10  5.0000D-01   5.0000D-01   1.0000E 00   7.0000E 00   1.0000E 12   0.0          4.3982D 01
   10   11   11  5.0000D-01   4.6875D-01   1.0000E 00   8.0000E 00   1.0000E 12   0.0          5.0265D 01
   11   12   12  4.6875D-01   0.0          1.0000E 00   8.9375E 00   1.0000E 12   0.0          5.6156D 01
===============================================================================================
DATA BLOCK  60                 EXTERNAL THERMAL CONNECTIONS

  NODS NODSB INDEX LTABH      POWER        DLONG        DRAD         HSURE        RSURE         AREAS
    12  2001     1     0     0.0          1.0000E 00   8.9375E 00   1.0000D 06   0.0          5.6156D 01
-----------------------------------------------------------------------------------------------
```

```
-----------------------------------------------------------------------------------------------------------------
DATA BLOCK  70                    BOUNDARY TEMPERATURE VARIATION.

 NODB INDEX LTABT    TEMPB           SLOPE            TIMEB
 2001     1    12  8.950000E 01                     1.200000E 02
                   8.450000E 01  -4.166666E-02      2.400000E 02
                   7.925000E 01  -4.375000E-02      3.600000E 02
                   7.600000E 01  -2.708333E-02      4.800000E 02
                   6.975000E 01  -5.208333E-02      6.000000E 02
                   8.225000E 01   1.041666E-01      7.200000E 02
                   1.037500E 02   1.791666E-01      8.400000E 02
                   1.190000E 02   1.270833E-01      9.600000E 02
                   1.300000E 02   9.166664E-02      1.080000E 03
                   1.380000E 02   6.666666E-02      1.200000E 03
                   1.322500E 02  -4.791667E-02      1.320000E 03
                   1.035000E 02  -2.395833E-01      1.440000E 03
=================================================================================================================
DATA BLOCK  90                   INITIAL TEMPERATURES

 NOTE INDEX          TT              AA               BB               GG
    1     1  1.152000E 02  0.0              0.0              0.0
    2     2  1.153000E 02  0.0              0.0              0.0
    3     3  1.160000E 02  0.0              0.0              0.0
    4     4  1.172000E 02  0.0              0.0              0.0
    5     5  1.184000E 02  0.0              0.0              0.0
    6     6  1.187000E 02  0.0              0.0              0.0
    7     7  1.173000E 02  0.0              0.0              0.0
    8     8  1.158000E 02  0.0              0.0              0.0
    9     9  1.132000E 02  0.0              0.0              0.0
   10    10  1.089000E 02  0.0              0.0              0.0
   11    11  1.051000E 02  0.0              0.0              0.0
   12    12  1.035000E 02  0.0              0.0              0.0
=================================================================================================================
DATA ENDED -10                     LAST CARD OF DATA DECK
=================================================================================================================
=================================================================================================================
MACHINE TIME (       ) =      0  SECONDS

SUMMARY OF INPUT DATA
BLOCK NUMBER              2      3      4      5      6      7      8      9     10     11     12
TIMES READ IN             1      0   1001   1001   2001      1   1000   1001   1000   1000   1000
ITEM NAME               MAT    KEM   VODE   NOD1   NODS  N ODB   NODG   NOTE  NODF1  NODEP  NODP1
MAXIMUM SIZE             15      5    355    950     60     20      5     12     50     10     75
UNMODIFIED SIZE           0      0      0      0      0      0      0      0      0      0      0

TABLES                 CAPT   CONT     QT     ZT     ET HSURTTEMPB     GT  FLOWT  TOTAL
                          0      0      0      0      0      0      1      0      0      1

                MAXIMUM ALLOWED TABLE LENGTH IS  12.

ARRAY STORAGE = 3*M11+M1*(1+M11)+M2*(11+7*M9)+M3*(5+9*M9)+56*M4+12*M5+M6*(12+3*M9)+M7*(5+3*M9)
                +M8*(3+3*M9)+M10*(9+3*M9)+5*M12+3*M9 =    39867.

OTHER TOTALS    NOSPEC NOGEN VORAD NORADS NMELT NREACT
                     1     0     1      0     0      0

MATERIAL SUMMARY

  NAME  MATL NODES   DENSITY       CAPACITY       TOT VOL       TOT MASS      TOT CAP       TOT HEAT
  SAND     1     7  5.44000E-02  1.90000E-01  1.03869E 02  5.65046E 00  1.07359E 00  1.26383E 02
  STEL     2     2  2.80700E-01  1.09000E-01  9.22843E 00  2.59042E 00  2.82356E-01  3.26968E 01
  AIR      3     3  4.36000E-05  2.40000E-01  1.37850E 02  6.01024E-03  1.44246E-03  1.56938E-01

SYSTEM TOTAL    12                            2.50947E 02  8.24689E 00  1.35739D 00  1.59237E 02
```

```
TRUMP OUTPUT DATA                                                                       DATA DECK    1

 *   MISSLE PROBLEM    ONE DIMENSIONAL
================================================================================================

  PRINTOUT    CYCLE   TOO FAST  TOO SLOW     KWIT     DELTMX          SMALL           TVARY       NUTS
     1          0         0         1          0    1.27605E-02     1.27605E-02     1.00000E 00     0

    TOTAL TIME     TIME STEP      HEAT FLOW     TEMP FROM FLUX   FLUX RATE      TEMP RATE
   1.00000E-12    1.00000E-12   -4.40992E-14   -3.24884E-14   -4.40993E-02   -3.24884E-02

    AVG TEMP     HEAT CAPACITY   HEAT CONTENT    GEN RATE        HEAT GEN       TEMP FROM GEN
   1.17311E 02    1.357390 00    1.59237E 02    0.0             0.0             0.0
================================================================================================

NODE        TEMP         DT            DDT          GE N RATE         W           H            F          CURE AT 280 F
  1     0.1152D 03   0.5224D-11   0.5224D 01    0.0           0.1496E-04   0.6785E-18   0.6785E-18    0.0
  2     0.1153D 03   0.3659D-13   0.3659D-01    0.0           0.3744E 01   0.1188E-14   0.1188E-14    0.0
  3     0.1160D 03   0.2959D-13   0.2959D-01    0.0           0.1130E 02   0.2883E-14   0.2883E-14    0.0
  4     0.1172D 03   0.1254D-13   0.1254D-01    0.0           0.1903E 02   0.2036E-14   0.2036E-14    0.0
  5     0.1184D 03  -0.1791D-13  -0.1791D-01    0.0           0.2691E 02  -0.4071E-14  -0.4071E-14    0.0
  6     0.1187D 03  -0.5341D-13  -0.5341D-01    0.0           0.3469E 02  -0.1561E-13  -0.1561E-13    0.0
  7     0.1173D 03  -0.9683D-13  -0.9683D-01    0.0           0.3071E 02  -0.2535E-13  -0.2535E-13    0.0
  8     0.1158D 03  -0.2327D-12  -0.2327D 00    0.0           0.3270E 02  -0.6571E-13  -0.6571E-13    0.0
  9     0.1132D 03   0.3622D-12   0.3622D 00    0.0           0.4838E-01   0.1548E-15   0.1548E-15    0.0
 10     0.1089D 03  -0.3672D-12  -0.3672D 00    0.0           0.5370E-01  -0.1810E-15  -0.1810E-15    0.0
 11     0.1051D 03  -0.4624D-10  -0.4624D 02    0.0           0.5486E-01  -0.2414E-13  -0.2414E-13    0.0
 12     0.9450D 02  -0.9000D 01   0.0           0.0           0.2891E-23  -0.2754E-24   0.8469E-13    0.0
================================================================================================
   MATERIAL DATA

    NAME   MATL     TOT CAP        TOT HEAT        AVG TEMP       TMELT          HMELT
    SAND     1    1.07359E 00    1.26383E 02    1.17720E 02    0.0            0.0
    STEL     2    2.82356E-01    3.26967E 01    1.15800E 02    0.0            0.0
    AIR      3    1.44246E-03    1.56938E-01    1.08799E 02    0.0            0.0
==========================================================================================
   NODE DATA

   NODE   MATL NTYPE    RADIUS       VOLUME        MASS        CAPACITY   CONDUCTIVITY     ZIP          SLIM
      1     1     0   0.1000E-02   0.1257E-04   0.6836D-06   0.1299D-06   0.2700D-03   0.6786D-05   0.1914D-01
      2     1     0   0.5010E 00   0.3142E 01   0.1709D 00   0.3247D-01   0.2700D-03   0.1705D-02   0.1905D 02
      3     1     0   0.1500E 01   0.9425E 01   0.5127D 00   0.9741D-01   0.2700D-03   0.5091D-02   0.1913D 02
      4     1     0   0.2500E 01   0.1571E 02   0.8545D 00   0.1624D 00   0.2700D-03   0.8482D-02   0.1914D 02
      5     1     0   0.3500E 01   0.2199E 02   0.1196D 01   0.2273D 00   0.2700D-03   0.1188D-01   0.1914D 02
      6     1     0   0.4500E 01   0.2827E 02   0.1538D 01   0.2922D 00   0.2700D-03   0.1648D-01   0.1773D 02
      7     1     0   0.5375E 01   0.2533E 02   0.1378D 01   0.2618D 00   0.2700D-03   0.3564D-01   0.7345D 01
      8     2     0   0.5875E 01   0.9228E 01   0.2590D 01   0.2824D 00   0.3640D-01   0.3235D-01   0.8728D 01
      9     3     0   0.6500E 01   0.4084E 02   0.1781D-02   0.4274D-03   0.2250D-04   0.2686D-02   0.1591D 00
     10     3     0   0.7500E 01   0.4712E 02   0.2055D-02   0.4931D-03   0.2250D-04   0.2157D-02   0.2286D 00
     11     3     0   0.8469E 01   0.4989E 02   0.2175D-02   0.5220D-03   0.2250D-04   0.3863D-02   0.1351D 00
     12     2     2   0.8938E 01   0.1000E-23   0.2807D-24   0.3060D-25   0.3640D-01   0.5616D 08   0.1000D-23
==========================================================================================
   INTERNAL CONNECTION DATA

        NOD1   NOD2     AREA         HINT         RINT            TRAN        HEAT FLOW    AVG RATE
          1      2    0.1257D-01   0.1000E 13   0.0             0.6786D-05   0.6785E-18   0.6785E-06
          2      3    0.6283D 01   0.1000E 13   0.0             0.1698D-02   0.1189E-14   0.1189E-02
          3      4    0.1257D 02   0.1000E 13   0.0             0.3393D-02   0.4071E-14   0.4071E-02
          4      5    0.1885D 02   0.1000E 13   0.0             0.5089D-02   0.6107E-14   0.6107E-02
          5      6    0.2513D 02   0.1000E 13   0.0             0.6786D-02   0.2036E-14   0.2036E-02
          6      7    0.3142D 02   0.1000E 13   0.0             0.9694D-02  -0.1357E-13  -0.1357E-01
          7      8    0.3613D 02   0.1000E 13   0.0             0.2595D-01  -0.3892E-13  -0.3892E-01
          8      9    0.3770D 02   0.1000E 13   0.0             0.1696D-02  -0.4410E-14  -0.4410E-02
          8     12    0.3770D 02   0.1000E-23   0.9760E-04      0.4705D-02  -0.1002E-12  -0.1002E 00
          9     10    0.4398D 02   0.1000E 13   0.0             0.9896D-03  -0.4255E-14  -0.4255E-02
         10     11    0.5027D 02   0.1000E 13   0.0             0.1167D-02  -0.4436E-14  -0.4436E-02
         11     12    0.5616D 02   0.1000E 13   0.0             0.2695D-02  -0.2857E-13  -0.2857E-01
==========================================================================================
   BOUNDARY NODE DATA

    NODB     TEMPB          HEAT FLOW      AVG RATE
    2001    9.4500E 01   -4.4099D-14   -4.4099E-02

   SYSTEM TOTAL           -4.4099E-14   -4.4099E-02
==========================================================================================
   FXTERNAL CONNECTION DATA

     NODS NODSB     AREAS          HSURE          POWER          RSURE          TRANS         HEAT FLOW     AVG RATE
      12   2001   5.6156D 01   1.0000D 06   0.0            0.0            5.6156D 07  -4.4099E-14  -4.4099E-02
==========================================================================================

   CYCLE     1 MADE NODE     1 A SPECIAL NODE
```

```
TRUMP OUTPUT DATA                                                                                        DATA DECK    1
    *   MISSLE PROBLEM    ONE DIMENSIONAL
==========================================================================================================================
     PRINTOUT    CYCLE   TOO FAST  TOO SLOW    KWIT     DELTMX          SMALL          TVARY          NUTS
         2          1        1        0          0    9.00862E-02    9.00862E-02    1.00000E 00       0

      TOTAL TIME     TIME STEP      HEAT FLOW    TEMP FROM FLUX   FLUX RATE     TEMP RATE
     1.27605E-02    1.27605E-02   -1.59315E-03   -1.17369E-03   -1.24850E-01   -9.19782E-02

       AVG TEMP     HEAT CAPACITY   HEAT CONTENT    GEN RATE       HEAT GEN      TEMP FROM GEN
     1.17310E 02     1.35739D 00    1.59235E 02    0.0            0.0           0.0
==========================================================================================================================
  NODE       TEMP        DT          DDT        GE N RATE        W            H             F          CURE AT 280 F
     1     0.1153D 03  0.6666D-01   0.3134D 01   0.0          0.1497E-04   0.8658E-08    0.8658E-08    0.0
     2     0.1153D 03  0.4669D-03   0.3659D-01   0.0          0.3744E 01   0.1516E-04    0.1516E-04    0.0
     3     0.1160D 03  0.3776D-03   0.2959D-01   0.0          0.1130E 02   0.3679E-04    0.3679E-04    0.0
     4     0.1172D 03  0.1600D-03   0.1254D-01   0.0          0.1903E 02   0.2598E-04    0.2598E-04    0.0
     5     0.1184D 03 -0.2286D-03  -0.1791D-01   0.0          0.2691E 02  -0.5195E-04   -0.5195E-04    0.0
     6     0.1187D 03 -0.6815D-03  -0.5341D-01   0.0          0.3469E 02  -0.1992E-03   -0.1992E-03    0.0
     7     0.1173D 03 -0.1236D-02  -0.9683D-01   0.0          0.3071E 02  -0.3235E-03   -0.3235E-03    0.0
     8     0.1158D 03 -0.2864D-02  -0.2244D 00   0.0          0.3270E 02  -0.8086E-03   -0.8086E-03    0.0
     9     0.1132D 03  0.4622D-02   0.3622D 00   0.0          0.4838E-01   0.1975E-05    0.1975E-05    0.0
    10     0.1089D 03 -0.4685D-02  -0.3672D 00   0.0          0.5370E-01  -0.2310E-05   -0.2310E-05    0.0
    11     0.1045D 03 -0.5512D 00  -0.4319D 02   0.0          0.5457E-01  -0.2877E-03   -0.2877E-03    0.0
    12     0.9450D 02 -0.5188D-03   0.0          0.0          0.2891E-23  -0.2754E-24    0.1231E-06    0.0
==========================================================================================================================
    MATERIAL DATA

      NAME   MATL       TOT CAP         TOT HEAT        AVG TEMP       TMELT          HMELT
      SAND     1     1.07359E 00     1.26383E 02     1.17720E 02     0.0            0.0
      STFL     2     2.82356E-01     3.26960E 01     1.15797E 02     0.0            0.0
      AIR      3     1.44246E-03     1.56650E-01     1.08599E 02     0.0            0.0
==================================================================================================================
    NODE DATA

    NODE  MATL  NTYPE    RADIUS        VOLUME        MASS         CAPACITY   CONDUCTIVITY      ZIP          SLIM
       1     1     4   0.1000E-02   0.1257E-04   0.6836D-06   0.1299D-06   0.2700D-03   0.6786D-05   0.1914D-01
       2     1     0   0.5010E 00   0.3142E 01   0.1709D 00   0.3247D-01   0.2700D-03   0.1705D-02   0.1905D 02
       3     1     0   0.1500E 01   0.9425E 01   0.5127D 00   0.9741D-01   0.2700D-03   0.5091D-02   0.1913D 02
       4     1     0   0.2500E 01   0.1571E 02   0.8545D 00   0.1624D 00   0.2700D-03   0.8482D-02   0.1914D 02
       5     1     0   0.3500E 01   0.2199E 02   0.1196D 01   0.2273D 00   0.2700D-03   0.1188D-01   0.1914D 02
       6     1     0   0.4500E 01   0.2827E 02   0.1538D 01   0.2922D 00   0.2700D-03   0.1648D-01   0.1773D 02
       7     1     0   0.5375E 01   0.2533E 02   0.1378D 01   0.2618D 00   0.2700D-03   0.3564D-01   0.7345D 01
       8     2     0   0.5875E 01   0.9228E 01   0.2590D 01   0.2824D 00   0.3640D-01   0.3224D-01   0.8758D 01
       9     3     0   0.6500E 01   0.4084E 02   0.1781D-02   0.4274D-03   0.2250D-04   0.2686D-02   0.1591D 00
      10     3     0   0.7500E 01   0.4712E 02   0.2055D-02   0.4931D-03   0.2250D-04   0.2157D-02   0.2286D 00
      11     3     0   0.8469E 01   0.4989E 02   0.2175D-02   0.5220D-03   0.2250D-04   0.3863D-02   0.1351D 00
      12     2     2   0.8938E 01   0.1000E-23   0.2807D-24   0.3060D-25   0.3640D-01   0.5616D 08   0.1000D-23
==================================================================================================================
    INTERNAL CONNECTION DATA

        NOD1   NOD2     AREA          HINT         RINT            TRAN         HEAT FLOW     AVG RATE
          1      2    0.1257D-01   0.1000E 13   0.0            0.6786D-05   0.8658E-08   0.6785E-06
          2      3    0.6283D 01   0.1000E 13   0.0            0.1698D-02   0.1517E-04   0.1189E-02
          3      4    0.1257D 02   0.1000E 13   0.0            0.3393D-02   0.5195E-04   0.4071E-02
          4      5    0.1885D 02   0.1000E 13   0.0            0.5089D-02   0.7793E-04   0.6107E-02
          5      6    0.2513D 02   0.1000E 13   0.0            0.6786D-02   0.2598E-04   0.2036E-02
          6      7    0.3142D 02   0.1000E 13   0.0            0.9694D-02  -0.1732E-03  -0.1357E-01
          7      8    0.3613D 02   0.1000E 13   0.0            0.2595D-01  -0.4967E-03  -0.3892E-01
          8      9    0.3770D 02   0.1000E 13   0.0            0.1696D-02  -0.5628E-04  -0.4410E-02
          8     12    0.3770D 02   0.1000E-23   0.9760E-04     0.4596D-02  -0.1249E-02  -0.9788E-01
          9     10    0.4398D 02   0.1000E 13   0.0            0.9896D-03  -0.5430E-04  -0.4255E-02
         10     11    0.5027D 02   0.1000E 13   0.0            0.1167D-02  -0.5661E-04  -0.4436E-02
         11     12    0.5616D 02   0.1000E 13   0.0            0.2695D-02  -0.3443E-03  -0.2698E-01
==================================================================================================================
    BOUNDARY NODE DATA

     NODB      TEMPB          HEAT FLOW     AVG RATE
     2001    9.4499E 01   -1.5931D-03   -1.2485E-01

    SYSTEM TOTAL          -1.5931E-03   -1.2485E-01
==================================================================================================================
    EXTERNAL CONNECTION DATA

      NODS NODSB     AREAS         HSURE        POWER        RSURE          TRANS       HEAT FLOW     AVG RATE
       12   2001   5.6156D 01   1.0000D 06   0.0          0.0           5.6156D 07  -1.5931E-03  -1.2485E-01
==================================================================================================================

    CYCLE     5 MADE NODE     9 A SPECIAL NODE
```

```
TRUMP OUTPUT DATA                                                                                    DATA DECK    1
*   MISSLE PROBLEM     ONE DIMENSIONAL
==========================================================================================================================
   PRINTOUT     CYCLE    TOO FAST  TOO SLOW      KWIT      DELTMX           SMALL            TVARY         NUTS
      3           15        6          0            0      1.18222E 01     1.00000E 00     1.00000E 00        7

     TOTAL TIME      TIME STEP        HEAT FLOW      TEMP FROM FLUX    FLUX RATE       TEMP RATE
    3.10774E 01     7.13691E 00      3.63609E 01      2.67874E 01     1.17001E 00     8.61958E-01

     AVG TEMP      HEAT CAPACITY    HEAT CONTENT      GEN RATE         HEAT GEN       TEMP FROM GEN
    1.15130E 02     1.35739D 00     1.56276E 02      0.0              0.0              0.0
==========================================================================================================================

 NODE          TEMP           DT              DDT           GE N RATE         W            H              F           CURE AT 280 F
   1        0.1163D 03    0.1909D 00     0.2675D-01     0.0           0.1510E-04    0.1395E-06     0.1395E-06    0.0
   2,       0.1163D 03    0.1909D 00     0.2674D-01     0.0           0.3776E 01    0.3165E-01     0.3165E-01    0.0
   3        0.1167D 03    0.1282D 00     0.1796D-01     0.0           0.1137E 02    0.7047E-01     0.7047E-01    0.0
   4        0.1174D 03   -0.6632D-02    -0.9292D-27     0.0           0.1905E 02    0.2600E-01     0.2600E-01    0.0
   5        0.1176D 03   -0.2374D 00    -0.3327D-01     0.0           0.2673E 02   -0.1786E 00    -0.1786E 00    0.0
   6        0.1165D 03   -0.5715D 00    -0.8007D-01     0.0           0.3405E 02   -0.6344E 00    -0.6344E 00    0.0
   7        0.1135D 03   -0.7947D 00    -0.1114D 00     0.0           0.2972E 02   -0.9912E 00    -0.9912E 00    0.0
   8        0.1113D 03   -0.8007D 00    -0.1122D 00     0.0           0.3142E 02   -0.1274E 01    -0.1274E 01    0.0
   9        0.1075D 03   -0.7063D 00    -0.9896D-01     0.0           0.4596E-01   -0.2417E-02    -0.2403E-02    0.0
  10        0.1011D 03   -0.5201D 00    -0.7288D-01     0.0           0.4985E-01   -0.3849E-02    -0.3832E-02    0.0
  11        0.9560D 02   -0.3643D 00    -0.5104D-01     0.0           0.4990E-01   -0.4961E-02    -0.4945E-02    0.0
  12        0.9321D 02   -0.2974D 00    -0.4167D-01     0.0           0.2852E-23   -0.3150E-24     0.3932E 02    0.0
==========================================================================================================================
    MATERIAL DATA

      NAME   MATL        TOT CAP         TOT HEAT        AVG TEMP        TMELT              HMELT
      SAND     1      1.07359E 00     1.24707E 02     1.16159E 02     0.0                0.0
      STEL     2      2.82356E-01     3.14232E 01     1.11290E 02     0.0                0.0
      AIR      3      1.44246E-03     1.45711E-01     1.01016E 02     0.0                0.0
===================================================================================================================
    NODE DATA

    NODE    MATL  NTYPE      RADIUS         VOLUME          MASS         CAPACITY   CONDUCTIVITY       ZIP           SLIM
       1       1      4   0.1000E-02    0.1257E-04    0.6836D-06    0.1299D-06    0.2700D-03    0.6786D-05    0.1914D-01
       2       1      0   0.5010E 00    0.3142E 01    0.1709D 00    0.3247D-01    0.2700D-03    0.1705D-02    0.1905D 02
       3       1      0   0.1500E 01    0.9425E 01    0.5127D 00    0.9741D-01    0.2700D-03    0.5091D-02    0.1913D 02
       4       1      0   0.2500E 01    0.1571E 02    0.8545D 00    0.1624D 00    0.2700D-03    0.8482D-02    0.1914D 02
       5       1      0   0.3500E 01    0.2199E 02    0.1196D 01    0.2273D 00    0.2700D-03    0.1188D-01    0.1914D 02
       6       1      0   0.4500E 01    0.2827E 02    0.1538D 01    0.2922D 00    0.2700D-03    0.1648D-01    0.1773D 02
       7       1      4   0.5375E 01    0.2533E 02    0.1378D 01    0.2618D 00    0.2700D-03    0.3564D-01    0.7345D 01
       8       2      4   0.5875E 01    0.9228E 01    0.2590D 01    0.2824D 00    0.3640D-01    0.3217D-01    0.8776D 01
       9       3      4   0.6500E 01    0.4084E 02    0.1781D-02    0.4274D-03    0.2250D-04    0.2686D-02    0.1591D 00
      10       3      4   0.7500E 01    0.4712E 02    0.2055D-02    0.4931D-03    0.2250D-04    0.2157D-02    0.2286D 00
      11       3      4   0.8469E 01    0.4989E 02    0.2175D-02    0.5220D-03    0.2250D-04    0.3863D-02    0.1351D 00
      12       2      2   0.8938E 01    0.1000E-23    0.2807D-24    0.3060D-25    0.3640D-01    0.5616D 08    0.1000D-23
===================================================================================================================
    INTERNAL CONNECTION DATA

         NOD1   NOD2      AREA           HINT           RINT              TRAN         HEAT FLOW      AVG RATE
            1      2   0.1257D-01    0.1000E 13    0.0               0.6786D-05    0.1395E-06    0.4490E-08
            2      3   0.6283D 01    0.1000E 13    0.0               0.1698D-02    0.3165E-01    0.1018E-02
            3      4   0.1257D 02    0.1000E 13    0.0               0.3393D-02    0.1021E 00    0.3286E-02
            4      5   0.1885D 02    0.1000E 13    0.0               0.5089D-02    0.1281E 00    0.4123E-02
            5      6   0.2513D 02    0.1000E 13    0.0               0.6786D-02   -0.5052E-01   -0.1626E-02
            6      7   0.3142D 02    0.1000E 13    0.0               0.9694D-02   -0.6849E 00   -0.2204E-01
            7      8   0.3613D 02    0.1000E 13    0.0               0.2595D-01   -0.1676E 01   -0.5394E-01
            8      9   0.3770D 02    0.1000E 13    0.0               0.1696D-02   -0.2084E 00   -0.6706E-02
            8     12   0.3770D 02    0.1000E-23    0.9760E-04        0.4530D-02   -0.2741E 01   -0.8821E-01
            9     10   0.4398D 02    0.1000E 13    0.0               0.9896D-03   -0.2108E 00   -0.6783E-02
           10     11   0.5027D 02    0.1000E 13    0.0               0.1167D-02   -0.2146E 00   -0.6906E-02
           11     12   0.5616D 02    0.1000E 13    0.0               0.2695D-02   -0.2196E 00   -0.7065E-02
===================================================================================================================
    BOUNDARY NODE DATA

     NODB      TEMPB          HEAT FLOW      AVG RATE
     2001    9.3205E 01     3.6361D 01     1.1700E 00

    SYSTEM TOTAL            3.6361E 01     1.1700E 00
===================================================================================================================
    EXTERNAL CONNECTION DATA

      NODS NODSB      AREAS          HSURE         POWER         RSURE          TRANS        HEAT FLOW    AVG RATE
        12  2001   5.6156D 01    1.0000D 06    0.0            0.0           5.6156D 07    3.6361E 01   1.1700E 00
===================================================================================================================

    CYCLE    21 MADE NODE     2 A SPECIAL NODE
```

```
TRUMP OUTPUT DATA                                                                                              DATA DECK    1
*   MISSLE PROBLEM    ONE DIMENSIONAL
==============================================================================================================================
   PRINTOUT     CYCLE    TOO FAST  TOO SLOW      KWIT      DELTMX            SMALL              TVARY           NUTS
      4           30        6         0            0      1.00000E 12      1.00000E 00       1.00000E 00         9

    TOTAL TIME       TIME STEP        HEAT FLOW       TEMP FROM FLUX    FLUX RATE        TEMP RATE
    2.38531E 02      1.94166E 01      7.70604E 02      5.67711E 02      3.23062E 00      2.38003E 00

     AVG TEMP       HEAT CAPACITY     HEAT CONTENT      GEN RATE          HEAT GEN         TEMP FROM GEN
    1.04224E 02      1.35739D 00      1.41473E 02      0.0               0.0               0.0
==============================================================================================================================
NODE          TEMP          DT              DDT             GE N RATE           W              H               F           CURE AT 280 F
  1       0.1126D 03   -0.7910D 00    -0.4074D-01        0.0            0.1463E-04    -0.3370E-06    -0.3373E-06      0.0
  2       0.1126D 03   -0.7910D 00    -0.4074D-01        0.0            0.3656E 01    -0.8752E-01    -0.8752E-01      0.0
  3       0.1118D 03   -0.8245D 00    -0.4247D-01        0.0            0.1089E 02    -0.4081E 00    -0.4081E 00      0.0
  4       0.1102D 03   -0.8775D 00    -0.4519D-01        0.0            0.1789E 02    -0.1140E 01    -0.1140E 01      0.0
  5       0.1076D 03   -0.9267D 00    -0.4773D-01        0.0            0.2447E 02    -0.2445E 01    -0.2445E 01      0.0
  6       0.1041D 03   -0.9491D 00    -0.4888D-01        0.0            0.3044E 02    -0.4252E 01    -0.4252E 01      0.0
  7       0.1002D 03   -0.9333D 00    -0.4907D-01        0.0            0.2624E 02    -0.4465E 01    -0.4465E 01      0.0
  8       0.9830D 02   -0.9155D 00    -0.4715D-01        0.0            0.2776E 02    -0.4940E 01    -0.4940E 01      0.0
  9       0.9546D 02   -0.8935D 00    -0.4602D-01        0.0            0.4079E-01    -0.7583E-02    -0.7462E-02      0.0
 10       0.9055D 02   -0.8555D 00    -0.4406D-01        0.0            0.4465E-01    -0.9047E-02    -0.8911E-02      0.0
 11       0.8638D 02   -0.8231D 00    -0.4239D-01        0.0            0.4509E-01    -0.9773E-02    -0.9652E-02      0.0
 12       0.8456D 02   -0.8090D 00    -0.4167D-01        0.0            0.2587E-23    -0.5795E-24     0.7884E 03      0.0
==============================================================================================================================
   MATERIAL DATA

     NAME   MATL       TOT CAP           TOT HEAT          AVG TEMP          TMELT              HMELT
     SAND     1      1.07359E 00       1.13585E 02       1.05800E 02      0.0                0.0
     STEL     2      2.82356E-01       2.77569E 01       9.83047E 01      0.0                0.0
     AIR      3      1.44246E-03       1.30534E-01       9.04939E 01      0.0                0.0
======================================================================================================================
   NODE DATA

   NODE   MATL  NTYPE    RADIUS          VOLUME          MASS          CAPACITY    CONDUCTIVITY       ZIP             SLIM
      1      1     4    0.1000E-02    0.1257E-04    0.6836D-06    0.1299D-06    0.2700D-03    0.6786D-05    0.1914D-01
      2      1     4    0.5010E 00    0.3142E 01    0.1709D 00    0.3247D-01    0.2700D-03    0.1705D-02    0.1905D 02
      3      1     4    0.1500E 01    0.9425E 01    0.5127D 00    0.9741D-01    0.2700D-03    0.5091D-02    0.1913D 02
      4      1     4    0.2500E 01    0.1571E 02    0.8545D 00    0.1624D 00    0.2700D-03    0.8482D-02    0.1914D 02
      5      1     4    0.3500E 01    0.2199E 02    0.1196D 01    0.2273D 00    0.2700D-03    0.1188D-01    0.1914D 02
      6      1     4    0.4500E 01    0.2827E 02    0.1538D 01    0.2922D 00    0.2700D-03    0.1648D-01    0.1773D 02
      7      1     4    0.5375E 01    0.2533E 02    0.1378D 01    0.2618D 00    0.2700D-03    0.3564D-01    0.7345D 01
      8      2     4    0.5875E 01    0.9228E 01    0.2590D 01    0.2824D 00    0.3640D-01    0.3192D-01    0.8845D 01
      9      3     4    0.6500E 01    0.4084E 02    0.1781D-02    0.4274D-03    0.2250D-04    0.2686D-02    0.1591D 00
     10      3     4    0.7500E 01    0.4712E 02    0.2055D-02    0.4931D-03    0.2250D-04    0.2157D-02    0.2286D 00
     11      3     4    0.8469E 01    0.4989E 02    0.2175D-02    0.5220D-03    0.2250D-04    0.3863D-02    0.1351D 00
     12      2     2    0.8938E 01    0.1000E-23    0.2807D-24    0.3060D-25    0.3640D-01    0.5616D 08    0.1000D-23
======================================================================================================================
   INTERNAL CONNECTION DATA

       NOD1   NOD2     AREA           HINT            RINT             TRAN         HEAT FLOW     AVG RATE
         1      2    0.1257D-01    0.1000E 13    0.0             0.6786D-05   -0.3373E-06   -0.1414E-08
         2      3    0.6283D 01    0.1000E 13    0.0             0.1698D-02   -0.8752E-01   -0.3669E-03
         3      4    0.1257D 02    0.1000E 13    0.0             0.3393D-02   -0.4956E 00   -0.2078E-02
         4      5    0.1885D 02    0.1000E 13    0.0             0.5089D-02   -0.1635E 01   -0.6856E-02
         5      6    0.2513D 02    0.1000E 13    0.0             0.6786D-02   -0.4080E 01   -0.1711E-01
         6      7    0.3142D 02    0.1000E 13    0.0             0.9694D-02   -0.8333E 01   -0.3493E-01
         7      8    0.3613D 02    0.1000E 13    0.0             0.2595D-01   -0.1280E 02   -0.5365E-01
         8      9    0.3770D 02    0.1000E 13    0.0             0.1696D-02   -0.1305E 01   -0.5470E-02
         8     12    0.3770D 02    0.1000E-23    0.9760E+04      0.4277D-02   -0.1643E 02   -0.6889E-01
         9     10    0.4398D 02    0.1000E 13    0.0             0.9896D-03   -0.1312E 01   -0.5501E-02
        10     11    0.5027D 02    0.1000E 13    0.0             0.1167D-02   -0.1321E 01   -0.5538E-02
        11     12    0.5616D 02    0.1000E 13    0.0             0.2695D-02   -0.1331E 01   -0.5579E-02
======================================================================================================================
   BOUNDARY NODE DATA

    NODB      TEMPB          HEAT FLOW      AVG RATE
    2001    8.4561E 01     7.7060D 02     3.2306E 00

   SYSTEM TOTAL            7.7060E 02     3.2306E 00
======================================================================================================================
   EXTERNAL CONNECTION DATA

     NODS  NODSB    AREAS          HSURE           POWER            RSURE            TRANS         HEAT FLOW     AVG RATE
      12   2001   5.6156D 01   1.0000D 06   0.0              0.0              5.6156D 07   7.7060E 02   3.2306E 00
======================================================================================================================
```

```
TRUMP OUTPUT DATA                                                                              DATA DECK    1

 *   MISSLE PROBLEM    ONE DIMENSIONAL
=========================================================================================================

  PRINTOUT     CYCLE   TOO FAST  TOO SLOW     KWIT     DELTMX           SMALL             TVARY       NUTS
     5           45        6         0          0    1.00000E 12     1.00000E 00      1.00000E 00     13

   TOTAL TIME      TIME STEP       HEAT FLOW     TEMP FROM FLUX   FLUX RATE       TEMP RATE
  5.51874E 02     1.78817E 01     2.26636E 03     1.66965E 03    4.10667E 00     3.02543E 00

   AVG TEMP       HEAT CAPACITY    HEAT CONTENT     GEN RATE          HEAT GEN        TEMP FROM GEN
  9.06828E 01      1.357390 00     1.23092E 02     0.0               0.0              0.0
=========================================================================================================

NODE          TEMP          DT           DDT           GE N RATE         W           H            F           CURE AT 280 F
  1       0.9863D 02  -0.7752D 00  -0.4335D-01    0.0             0.1281E-04  -0.2152E-05  -0.2150E-05     0.0
  2       0.9863D 02  -0.7752D 00  -0.4335D-01    0.0             0.3203E 01  -0.5412E 00  -0.5412E 00     0.0
  3       0.9781D 02  -0.7677D 00  -0.4293D-01    0.0             0.9528E 01  -0.1772E 01  -0.1772E 01     0.0
  4       0.9617D 02  -0.7539D 00  -0.4216D-01    0.0             0.1561E 02  -0.3415E 01  -0.3415E 01     0.0
  5       0.9373D 02  -0.7376D 00  -0.4125D-01    0.0             0.2130E 02  -0.5607E 01  -0.5607E 01     0.0
  6       0.9052D 02  -0.7282D 00  -0.4072D-01    0.0             0.2645E 02  -0.8235E 01  -0.8235E 01     0.0
  7       0.8704D 02  -0.7385D 00  -0.4130D-01    0.0             0.2279E 02  -0.7923E 01  -0.7922E 01     0.0
  8       0.8532D 02  -0.7513D 00  -0.4201D-01    0.0             0.2409E 02  -0.8607E 01  -0.8607E 01     0.0
  9       0.8261D 02  -0.7886D 00  -0.4410D-01    0.0             0.3530E-01  -0.1307E-01  -0.1293E-01     0.0
 10       0.7795D 02  -0.8532D 00  -0.4771D-01    0.0             0.3844E-01  -0.1526E-01  -0.1511E-01     0.0
 11       0.7399D 02  -0.9081D 00  -0.5079D-01    0.0             0.3862E-01  -0.1624E-01  -0.1611E-01     0.0
 12       0.7226D 02  -0.9313D 00  -0.5208D-01    0.0             0.2211E-23  -0.9559E-24   0.2303E 04     0.0
=========================================================================================================
    MATFRIAL DATA

     NAME   MATL       TOT CAP          TOT HEAT         AVG TEMP       TMELT            HMELT
     SAND     1      1.07359E 00      9.88896E 01      9.21114E 01     0.0              0.0
     STEL     2      2.82356E-01      2.40896E 01      8.53166E 01     0.0              0.0
     AIR      3      1.44246E-03      1.12364E-01      7.78977E 01     0.0              0.0
    =================================================================================================
    NODE DATA

    NODE   MATL NTYPE    RADIUS        VOLUME        MASS          CAPACITY   CONDUCTIVITY     ZIP          SLIM
       1     1     4    0.1000E-02   0.1257E-04   0.6836D-06   0.1299D-06   0.2700D-03   0.6786D-05   0.1914D-01
       2     1     4    0.5010E 00   0.3142E 01   0.1709D 00   0.3247D-01   0.2700D-03   0.1705D-02   0.1905D 02
       3     1     4    0.1500E 01   0.9425E 01   0.5127D 00   0.9741D-01   0.2700D-03   0.5091D-02   0.1913D 02
       4     1     4    0.2500E 01   0.1571E 02   0.8545D 00   0.1624D 00   0.2700D-03   0.8482D-02   0.1914D 02
       5     1     4    0.3500E 01   0.2199E 02   0.1196D 01   0.2273D 00   0.2700D-03   0.1188D-01   0.1914D 02
       6     1     4    0.4500E 01   0.2827E 02   0.1538D 01   0.2922D 00   0.2700D-03   0.1648D-01   0.1773D 02
       7     1     4    0.5375E 01   0.2533E 02   0.1378D 01   0.2618D 00   0.2700D-03   0.3564D-01   0.7345D 01
       8     2     4    0.5875E 01   0.9228E 01   0.2590D 01   0.2824D 00   0.3640D-01   0.3164D-01   0.8925D 01
       9     3     4    0.6500E 01   0.4084E 02   0.1781D-02   0.4274D-03   0.2250D-04   0.2686D-02   0.1591D 00
      10     3     4    0.7500E 01   0.4712E 02   0.2055D-02   0.4931D-03   0.2250D-04   0.2157D-02   0.2286D 00
      11     3     4    0.8469E 01   0.4989E 02   0.2175D-02   0.5220D-03   0.2250D-04   0.3863D-02   0.1351D 00
      12     2     2    0.8938E 01   0.1000E-23   0.2807D-24   0.3060D-25   0.3640D-01   0.5616D 08   0.1000D-23
    =================================================================================================
    INTFRNAL CONNECTION DATA

         NOD1  NOD2      AREA         HINT          RINT             TRAN        HEAT FLOW     AVG RATE
           1     2    0.1257D-01   0.1000E 13   0.0             0.6786D-05  -0.2150E-05  -0.3895E-08
           2     3    0.6283D 01   0.1000E 13   0.0             0.1698D-02  -0.5412E 00  -0.9806E-03
           3     4    0.1257D 02   0.1000E 13   0.0             0.3393D-02  -0.2313E 01  -0.4192E-02
           4     5    0.1885D 02   0.1000E 13   0.0             0.5089D-02  -0.5728E 01  -0.1038E-01
           5     6    0.2513D 02   0.1000E 13   0.0             0.6786D-02  -0.1134E 02  -0.2054E-01
           6     7    0.3142D 02   0.1000E 13   0.0             0.9694D-02  -0.1957E 02  -0.3546E-01
           7     8    0.3613D 02   0.1000E 13   0.0             0.2595D-01  -0.2749E 02  -0.4982E-01
           8     9    0.3770D 02   0.1000E 13   0.0             0.1696D-02  -0.2748E 01  -0.4979E-02
           8    12    0.3770D 02   0.1000E-23   0.9760E-04      0.3992D-02  -0.3335E 02  -0.6043E-01
           9    10    0.4398D 02   0.1000E 13   0.0             0.9896D-03  -0.2761E 01  -0.5003E-02
          10    11    0.5027D 02   0.1000E 13   0.0             0.1167D-02  -0.2776E 01  -0.5030E-02
          11    12    0.5616D 02   0.1000E 13   0.0             0.2695D-02  -0.2792E 01  -0.5059E-02
    =================================================================================================
    BOUNDARY NODE DATA

     NODB     TFMPB        HEAT FLOW     AVG RATE
     2001    7.2257E 01   2.2664D 03    4.1067E 00

    SYSTFM TOTAL          2.2664E 03    4.1067E 00
    =================================================================================================
    FXTERNAL CONNECTION DATA

      NODS NODSB    AREAS        HSURE         POWER          RSURE           TRANS        HEAT FLOW     AVG RATE
       12  2001  5.6156D 01  1.0000D 06  0.0              0.0           5.6156D 07   2.2664E 03   4.1067E 00
    =================================================================================================
    WILL REPEAT CYCLE     49      DTMAX = 2.219E 00 DTPRE = 2.219E 00 DELT = 2.130D 01 SUMTIM = 6.083E 02
    WILL RFPEAT CYCLE     49      DTMAX = 2.109E 00 DTPRF = 1.109E 00 DELT = 1.065D 01 SUMTIM = 6.083E 02
```

```
TRUMP OUTPUT DATA                                                                         DATA DECK    1

*   MISSLE PROBLEM    ONE DIMENSIONAL
=====================================================================================================

  PRINTOUT    CYCLE   TOO FAST  TOO SLOW     KWIT     DELTMX          SMALL           TVARY        NUTS
     6          60        6         0          0    1.00000E 12    1.00000E 00    1.00000E 00      7

    TOTAL TIME      TIME STEP       HEAT FLOW    TEMP FROM FLUX   FLUX RATE        TEMP RATE
   6.97209E 02     9.34838E 00    -7.26409E 03   -5.35153E 03    -1.04188E 01    -7.67565E 00

    AVG TEMP       HEAT CAPACITY   HEAT CONTENT    GEN RATE         HEAT GEN        TEMP FROM GEN
   8.62795E 01     1.35739D 00    1.17115E 02    0.0              0.0              0.0
=====================================================================================================

NODE        TEMP         DT           DDT         GE N RATE        W           H            F           CURE AT 280 F
  1     0.9253D 02  -0.3751D 00  -0.3852D-01    0.0          0.1202E-04  -0.2945E-05  -0.2942E-05    0.0
  2     0.9253D 02  -0.3751D 00  -0.3852D-01    0.0          0.3004E 01  -0.7395E 00  -0.7395E 00    0.0
  3     0.9177D 02  -0.3626D 00  -0.3724D-01    0.0          0.8939E 01  -0.2361E 01  -0.2361E 01    0.0
  4     0.9028D 02  -0.3297D 00  -0.3386D-01    0.0          0.1466E 02  -0.4370E 01  -0.4370E 01    0.0
  5     0.8819D 02  -0.2599D 00  -0.2668D-01    0.0          0.2005E 02  -0.6867E 01  -0.6867E 01    0.0
  6     0.8572D 02  -0.1295D 00  -0.1330D-01    0.0          0.2505E 02  -0.9638E 01  -0.9638E 01    0.0
  7     0.8362D 02   0.5542D-01   0.5691D-02    0.0          0.2189E 02  -0.8818E 01  -0.8818E 01    0.0
  8     0.8290D 02   0.1577D 00   0.1619D-01    0.0          0.2341E 02  -0.9288E 01  -0.9288E 01    0.0
  9     0.8226D 02   0.3356D 00   0.3446D-01    0.0          0.3515E-01  -0.1322E-01  -0.1296E-01    0.0
 10     0.8116D 02   0.6306D 00   0.6476D-01    0.0          0.4002E-01  -0.1368E-01  -0.1338E-01    0.0
 11     0.8025D 02   0.8684D 00   0.8917D-01    0.0          0.4189E-01  -0.1297E-01  -0.1272E-01    0.0
 12     0.7987D 02   0.9547D 00   0.9803D-01    0.0          0.2444E-23  -0.7231E-24  -0.7222E 04    0.0
=====================================================================================================
    MATERIAL DATA

      NAME   MATL       TOT CAP          TOT HEAT         AVG TEMP        TMELT            HMELT
      SAND     1      1.07359E 00      9.35891E 01      8.71742E 01    0.0              0.0
      STEL     2      2.82356E-01      2.34084E 01      8.29039E 01    0.0              0.0
      AIR      3      1.44246E-03      1.17062E-01      8.11543E 01    0.0              0.0
    =================================================================================================
    NODE DATA

    NODE   MATL  NTYPE     RADIUS        VOLUME         MASS         CAPACITY   CONDUCTIVITY     ZIP           SLIM
      1      1     4     0.1000E-02   0.1257E-04   0.6836D-06   0.1299D-06   0.2700D-03   0.6786D-05   0.1914D-01
      2      1     4     0.5010E 00   0.3142E 01   0.1709D 00   0.3247D-01   0.2700D-03   0.1705D-02   0.1905D 02
      3      1     4     0.1500E 01   0.9425E 01   0.5127D 00   0.9741D-01   0.2700D-03   0.5091D-02   0.1913D 02
      4      1     4     0.2500E 01   0.1571E 02   0.8545D 00   0.1624D 00   0.2700D-03   0.8482D-02   0.1914D 02
      5      1     4     0.3500E 01   0.2199E 02   0.1196D 01   0.2273D 00   0.2700D-03   0.1188D-01   0.1914D 02
      6      1     4     0.4500E 01   0.2827E 02   0.1538D 01   0.2922D 00   0.2700D-03   0.1648D-01   0.1773D 02
      7      1     4     0.5375E 01   0.2533E 02   0.1378D 01   0.2618D 00   0.2700D-03   0.3564D-01   0.7345D 01
      8      2     4     0.5875E 01   0.9228E 01   0.2590D 01   0.2824D 00   0.3640D-01   0.3168D-01   0.8913D 01
      9      3     4     0.6500E 01   0.4084E 02   0.1781D-02   0.4274D-03   0.2250D-04   0.2686D-02   0.1591D 00
     10      3     4     0.7500E 01   0.4712E 02   0.2055D-02   0.4931D-03   0.2250D-04   0.2157D-02   0.2286D 00
     11      3     4     0.8469E 01   0.4989E 02   0.2175D-02   0.5220D-03   0.2250D-04   0.3863D-02   0.1351D 00
     12      2     2     0.8938E 01   0.1000E-23   0.2807D-24   0.3060D-25   0.3640D-01   0.5616D 08   0.1000D-23
    =================================================================================================
    INTERNAL CONNECTION DATA

        NOD1   NOD2      AREA          HINT          RINT            TRAN        HEAT FLOW     AVG RATE
          1      2    0.1257D-01   0.1000E 13   0.0             0.6786D-05  -0.3118E-05  -0.4472E-08
          2      3    0.6283D 01   0.1000E 13   0.0             0.1698D-02  -0.7833E 00  -0.1123E-02
          3      4    0.1257D 02   0.1000E 13   0.0             0.3393D-02  -0.3275E 01  -0.4697E-02
          4      5    0.1885D 02   0.1000E 13   0.0             0.5089D-02  -0.7862E 01  -0.1128E-01
          5      6    0.2513D 02   0.1000E 13   0.0             0.6786D-02  -0.1503E 02  -0.2155E-01
          6      7    0.3142D 02   0.1000E 13   0.0             0.9694D-02  -0.2503E 02  -0.3590E-01
          7      8    0.3613D 02   0.1000E 13   0.0             0.2595D-01  -0.3410E 02  -0.4891E-01
          8      9    0.3770D 02   0.1000E 13   0.0             0.1696D-02  -0.3363E 01  -0.4823E-02
          8     12    0.3770D 02   0.1000E-23   0.9760E-04      0.4034D-02  -0.4020E 02  -0.5767E-01
          9     10    0.4398D 02   0.1000E 13   0.0             0.9896D-03  -0.3376E 01  -0.4841E-02
         10     11    0.5027D 02   0.1000E 13   0.0             0.1167D-02  -0.3388E 01  -0.4859E-02
         11     12    0.5616D 02   0.1000E 13   0.0             0.2695D-02  -0.3399E 01  -0.4875E-02
    =================================================================================================
    BOUNDARY NODE DATA

     NODB     TEMPB        HEAT FLOW     AVG RATE
     2001   7.9876E 01  -7.2641D 03   -1.0419E 01

    SYSTEM TOTAL          -7.2641E 03   -1.0419E 01
    =================================================================================================
    EXTERNAL CONNECTION DATA

      NODS NODSB    AREAS         HSURE        POWER          RSURE          TRANS       HEAT FLOW     AVG RATE
        12  2001  5.6156D 01  1.00000D 06  0.0            0.0            5.6156D 07 -7.2641E 03 -1.0419E 01
    =================================================================================================
```

```
TRUMP OUTPUT DATA                                                                              DATA DECK     1
   *   MISSLE PROBLEM    ONE DIMENSIONAL
==============================================================================================================
    PRINTOUT     CYCLE    TOO FAST  TOO SLOW      KWIT      DELTMX           SMALL            TVARY       NUTS
        7          75         6         0           0     1.00000E 12     1.00000E 00     1.00000E 00       4

     TOTAL TIME      TIME STEP      HEAT FLOW     TEMP FROM FLUX   FLUX RATE      TEMP RATE
    7.90942E 02     5.57991E 00   -7.70914E 03   -5.67940E 03   -9.74678E 00   -7.18055E 00

     AVG TEMP     HEAT CAPACITY   HEAT CONTENT     GEN RATE          HEAT GEN       TEMP FROM GEN
    8.70130E 01    1.35739D 00    1.18110E 02    0.0               0.0             0.0
==============================================================================================================

NODE          TEMP         DT            DDT          GE N RATE         W            H            F           CURE AT 280 F
   1      0.8934D 02  -0.1498D 00  -0.2684D-01    0.0           0.1160E-04  -0.3359E-05  -0.3354E-05    0.0
   2      0.8934D 02  -0.1498D 00  -0.2684D-01    0.0           0.2901E 01  -0.8430E 00  -0.8430E 00    0.0
   3      0.8883D 02  -0.1280D 00  -0.2293D-01    0.0           0.8654E 01  -0.2646E 01  -0.2646E 01    0.0
   4      0.8794D 02  -0.8000D-01  -0.1434D-01    0.0           0.1428E 02  -0.4751E 01  -0.4751E 01    0.0
   5      0.8691D 02   0.2871D-02   0.5145D-27    0.0           0.1975E 02  -0.7158E 01  -0.7158E 01    0.0
   6      0.8618D 02   0.1329D 00   0.2381D-01    0.0           0.2519E 02  -0.9504E 01  -0.9504E 01    0.0
   7      0.8642D 02   0.2977D 00   0.5335D-01    0.0           0.2262E 02  -0.8084E 01  -0.8084E 01    0.0
   8      0.8706D 02   0.3849D 00   0.6899D-01    0.0           0.2458E 02  -0.8115E 01  -0.8114E 01    0.0
   9      0.8866D 02   0.5124D 00   0.9184D-01    0.0           0.3789E-01  -0.1049E-01  -0.1008E-01    0.0
  10      0.9146D 02   0.7321D 00   0.1312D 00    0.0           0.4510E-01  -0.8602E-02  -0.8136E-02    0.0
  11      0.9388D 02   0.9187D 00   0.1646D 00    0.0           0.4900E-01  -0.5857E-02  -0.5452E-02    0.0
  12      0.9496D 02   0.1000D 01   0.1792D 00    0.0           0.2905E-23  -0.2613E-24  -0.7668E 04    0.0
==============================================================================================================
    MATERIAL DATA

      NAME   MATL      TOT CAP          TOT HEAT         AVG TEMP        TMELT           HMELT
      SAND     1     1.07359E 00     9.33965E 01     8.69948E 01    0.0             0.0
      STEL     2     2.82356E-01     2.45817E 01     8.70594E 01    0.0             0.0
      AIR      3     1.44246E-03     1.31993E-01     9.15055E 01    0.0             0.0
=======================================================================================================
    NODE DATA

    NODE   MATL NTYPE    RADIUS        VOLUME        MASS          CAPACITY   CONDUCTIVITY     ZIP          SLIM
       1     1     4   0.1000E-02   0.1257E-04   0.6836D-06   0.1299D-06   0.2700D-03   0.6786D-05   0.1914D-01
       2     1     4   0.5010E 00   0.3142E 01   0.1709D 00   0.3247D-01   0.2700D-03   0.1705D-02   0.1905D 02
       3     1     4   0.1500E 01   0.9425E 01   0.5127D 00   0.9741D-01   0.2700D-03   0.5091D-02   0.1913D 02
       4     1     4   0.2500E 01   0.1571E 02   0.8545D 00   0.1624D 00   0.2700D-03   0.8482D-02   0.1914D 02
       5     1     4   0.3500E 01   0.2199E 02   0.1196D 01   0.2273D 00   0.2700D-03   0.1188D-01   0.1914D 02
       6     1     4   0.4500E 01   0.2827E 02   0.1538D 01   0.2922D 00   0.2700D-03   0.1648D-01   0.1773D 02
       7     1     4   0.5375E 01   0.2533E 02   0.1378D 01   0.2618D 00   0.2700D-03   0.3564D-01   0.7345D 01
       8     2     4   0.5875E 01   0.9228E 01   0.2590D 01   0.2824D 00   0.3640D-01   0.3190D-01   0.8853D 01
       9     3     4   0.6500E 01   0.4084E 02   0.1781D-02   0.4274D-03   0.2250D-04   0.2686D-02   0.1591D 00
      10     3     4   0.7500E 01   0.4712E 02   0.2055D-02   0.4931D-03   0.2250D-04   0.2157D-02   0.2286D 00
      11     3     4   0.8469E 01   0.4989E 02   0.2175D-02   0.5220D-03   0.2250D-04   0.3863D-02   0.1351D 00
      12     2     2   0.8938E 01   0.1000E-23   0.2807D-24   0.3060D-25   0.3640D-01   0.5616D 08   0.1000D-23
=======================================================================================================
    INTERNAL CONNECTION DATA

         NOD1    NOD2      AREA          HINT          RINT              TRAN          HEAT FLOW     AVG RATE
            1       2   0.1257D-01   0.1000E 13   0.0               0.6786D-05  -0.3529E-05  -0.4461E-08
            2       3   0.6283D 01   0.1000E 13   0.0               0.1698D-02  -0.8869E 00  -0.1121E-02
            3       4   0.1257D 02   0.1000E 13   0.0               0.3393D-02  -0.3664E 01  -0.4633E-02
            4       5   0.1885D 02   0.1000E 13   0.0               0.5089D-02  -0.8632E 01  -0.1091E-01
            5       6   0.2513D 02   0.1000E 13   0.0               0.6786D-02  -0.1609E 02  -0.2034E-01
            6       7   0.3142D 02   0.1000E 13   0.0               0.9694D-02  -0.2595E 02  -0.3281E-01
            7       8   0.3613D 02   0.1000E 13   0.0               0.2595D-01  -0.3429E 02  -0.4336E-01
            8       9   0.3770D 02   0.1000E 13   0.0               0.1696D-02  -0.3292E 01  -0.4162E-02
            8      12   0.3770D 02   0.1000E-23   0.9760E-04        0.4251D-02  -0.3929E 02  -0.4968E-01
            9      10   0.4398D 02   0.1000E 13   0.0               0.9896D-03  -0.3302E 01  -0.4175E-02
           10      11   0.5027D 02   0.1000E 13   0.0               0.1167D-02  -0.3309E 01  -0.4184E-02
           11      12   0.5616D 02   0.1000E 13   0.0               0.2695D-02  -0.3313E 01  -0.4188E-02
=======================================================================================================
    BOUNDARY NODE DATA

     NODB      TEMPB           HEAT FLOW      AVG RATE
     2001    9.4960E 01    -7.7092D 03    -9.7468E 00

    SYSTEM TOTAL           -7.7092E 03    -9.7468E 00
=======================================================================================================
    EXTERNAL CONNECTION DATA

      NODS NODSB     AREAS         HSURE          POWER          RSURE          TRANS         HEAT FLOW     AVG RATE
        12  2001   5.6156D 01   1.0000D 06    0.0            0.0            5.6156D 07   -7.7091E 03   -9.7468E 00
=======================================================================================================
```

```
TRUMP OUTPUT DATA                                                                                     DATA DECK    1

  *   MISSLE PROBLEM    ONE DIMENSIONAL
=========================================================================================================================

    PRINTOUT     CYCLE   TOO FAST  TOO SLOW     KWIT      DELTMX            SMALL             TVARY         NUTS
       8           90        6          0          0     1.00000E 12     1.00000E 00      1.00000E 00       4

     TOTAL TIME     TIME STEP      HEAT FLOW     TEMP FROM FLUX   FLUX RATE       TEMP RATE
    8.84236E 02    7.80307E 00   -1.02246E 04   -7.53259E 03   -1.15632E 01    -8.51876E 00

     AVG TEMP      HEAT CAPACITY    HEAT CONTENT     GEN RATE         HEAT GEN       TEMP FROM GEN
    9.09457F 01     1.35739D 00     1.23448E 02    0.0              0.0             0.0
=========================================================================================================================

 NODE        TEMP          DT              DDT          GE N RATE         W              H              F           CURE AT 280 F
    1      0.8797D 02  -0.2100D-01   -0.2691D-02     0.0            0.1143E-04   -0.3537E-05   -0.3514E-05    0.0
    2      0.8797D 02  -0.2097D-01   -0.2687D-02     0.0            0.2857E 01   -0.8874E 00   -0.8874E 00    0.0
    3      0.8794D 02   0.2410D-01    0.3088D-02     0.0            0.8567E 01   -0.2734E 01   -0.2734E 01    0.0
    4      0.8804D 02   0.1159D 00    0.1485D-01     0.0            0.1429E 02   -0.4734E 01   -0.4734E 01    0.0
    5      0.8862D 02   0.2544D 00    0.3260D-01     0.0            0.2014E 02   -0.6770E 01   -0.6770E 01    0.0
    6      0.9017D 02   0.4311D 00    0.5525D-01     0.0            0.2635E 02   -0.8337E 01   -0.8337E 01    0.0
    7      0.9294D 02   0.5981D 00    0.7665D-01     0.0            0.2433E 02   -0.6376E 01   -0.6375E 01    0.0
    8      0.9476D 02   0.6662D 00    0.8537D-01     0.0            0.2675E 02   -0.5942E 01   -0.5941E 01    0.0
    9      0.9777D 02   0.7346D 00    0.9415D-01     0.0            0.4178E-01   -0.6596E-02   -0.6156E-02    0.0
   10      0.1030D 03   0.8510D 00    0.1091D 00     0.0            0.5077E-01   -0.2926E-02   -0.2425E-02    0.0
   11      0.1074D 03   0.9485D 00    0.1216D 00     0.0            0.5607E-01    0.1211E-02    0.1645E-02    0.0
   12      0.1094D 03   0.9916D 00    0.1271D 00     0.0            0.3346E-23    0.1797E-24   -0.1019E 05    0.0
=========================================================================================================================
    MATERIAL DATA

      NAME   MATL        TOT CAP          TOT HEAT         AVG TEMP          TMELT            HMELT
      SAND     1       1.07359E 00      9.65448E 01      8.99273E 01      0.0              0.0
      STEL     2       2.82356E-01      2.67550E 01      9.47563E 01      0.0              0.0
      AIR      3       1.44246E-03      1.48626E-01      1.03037E 02      0.0              0.0
    ===================================================================================================================
    NODE DATA

    NODE   MATL NTYPE    RADIUS        VOLUME          MASS         CAPACITY   CONDUCTIVITY       ZIP          SLIM
       1     1     4   0.1000E-02   0.1257E-04   0.6836D-06   0.1299D-06   0.2700D-03   0.6786D-05   0.1914D-01
       2     1     4   0.5010E 00   0.3142E 01   0.1709D 00   0.3247D-01   0.2700D-03   0.1705D-02   0.1905D 02
       3     1     4   0.1500E 01   0.9425E 01   0.5127D 00   0.9741D-01   0.2700D-03   0.5091D-02   0.1913D 02
       4     1     4   0.2500E 01   0.1571E 02   0.8545D 00   0.1624D 00   0.2700D-03   0.8482D-02   0.1914D 02
       5     1     4   0.3500E 01   0.2199E 02   0.1196D 01   0.2273D 00   0.2700D-03   0.1188D-01   0.1914D 02
       6     1     4   0.4500E 01   0.2827E 02   0.1538D 01   0.2922D 00   0.2700D-03   0.1648D-01   0.1773D 02
       7     1     4   0.5375E 01   0.2533E 02   0.1378D 01   0.2618D 00   0.2700D-03   0.3564D-01   0.7345D 01
       8     2     4   0.5875E 01   0.9228E 01   0.2590D 01   0.2824D 00   0.3640D-01   0.3216D-01   0.8781D 01
       9     3     4   0.6500E 01   0.4084E 02   0.1781D-02   0.4274D-03   0.2250D-04   0.2686D-02   0.1591D 00
      10     3     4   0.7500E 01   0.4712E 02   0.2055D-02   0.4931D-03   0.2250D-04   0.2157D-02   0.2286D 00
      11     3     4   0.8469E 01   0.4989E 02   0.2175D-02   0.5220D-03   0.2250D-04   0.3863D-02   0.1351D 00
      12     2     2   0.8938E 01   0.1000E-23   0.2807D-24   0.3060D-25   0.3640D-01   0.5616D 08   0.1000D-23
    ===================================================================================================================
    INTERNAL CONNECTION DATA

        NOD1   NOD2     AREA           HINT          RINT              TRAN        HEAT FLOW     AVG RATE
          1      2    0.1257D-01   0.1000E 13   0.0             0.6786D-05  -0.3689E-05  -0.4172E-08
          2      3    0.6283D 01   0.1000E 13   0.0             0.1698D-02  -0.9313E 00  -0.1053E-02
          3      4    0.1257D 02   0.1000E 13   0.0             0.3393D-02  -0.3796E 01  -0.4293E-02
          4      5    0.1885D 02   0.1000E 13   0.0             0.5089D-02  -0.8747E 01  -0.9892E-02
          5      6    0.2513D 02   0.1000E 13   0.0             0.6786D-02  -0.1581E 02  -0.1789E-01
          6      7    0.3142D 02   0.1000E 13   0.0             0.9694D-02  -0.2451E 02  -0.2772E-01
          7      8    0.3613D 02   0.1000E 13   0.0             0.2595D-01  -0.3115E 02  -0.3522E-01
          8      9    0.3770D 02   0.1000E 13   0.0             0.1696D-02  -0.2903E 01  -0.3283E-02
          8     12    0.3770D 02   0.1000E-23   0.9760E-04      0.4511D-02  -0.3436E 02  -0.3886E-01
          9     10    0.4398D 02   0.1000E 13   0.0             0.9896D-03  -0.2909E 01  -0.3290E-02
         10     11    0.5027D 02   0.1000E 13   0.0             0.1167D-02  -0.2910E 01  -0.3291E-02
         11     12    0.5616D 02   0.1000E 13   0.0             0.2695D-02  -0.2907E 01  -0.3287E-02
    ===================================================================================================================
    BOUNDARY NODE DATA

     NODB     TEMPB          HEAT FLOW     AVG RATE
     2001    1.0937E 02   -1.0225D 04   -1.1563E 01

    SYSTEM TOTAL           -1.0225E 04   -1.1563E 01
    ===================================================================================================================
    EXTERNAL CONNECTION DATA

      NODS NODSB    AREAS         HSURE         POWER           RSURE          TRANS        HEAT FLOW     AVG RATE
       12   2001   5.6156D 01   1.0000D 06   0.0             0.0            5.6156D 07  -1.0225E 04  -1.1563E 01
    ===================================================================================================================
```

```
TRUMP OUTPUT DATA                                                                                DATA DECK     1
*   MISSLE PROBLEM     ONE DIMENSIONAL
=========================================================================================================================
  PRINTOUT     CYCLE    TOO FAST   TOO SLOW      KWIT      DELTMX           SMALL             TVARY        NUTS
     9          105        6          0            0      1.00000E 12     1.00000E 00      1.00000E 00      5

   TOTAL TIME      TIME STEP       HEAT FLOW     TEMP FROM FLUX   FLUX RATE      TEMP RATE
  1.01237F 03     1.07468E 01    -1.15326E 04    -8.49616E 03   -1.13916E 01    -8.39233E 00

   AVG TEMP      HEAT CAPACITY    HEAT CONTENT     GEN RATE         HEAT GEN        TEMP FROM GEN
  9.89246E 01     1.357390 00     1.34279E 02     0.0              0.0              0.0
=========================================================================================================================

NODE         TEMP           DT              DDT            GE N RATE           W            H              F             CURE AT 280 F
  1       0.9018D 02    0.3557D 00      0.3310D-01      0.0                0.1171E-04   -0.3250E-05   -0.3208E-05    0.0
  2       0.9018D 02    0.3558D 00      0.3310D-01      0.0                0.2928E 01   -0.8158E 00   -0.8158E 00    0.0
  3       0.9083D 02    0.4054D 00      0.3772D-01      0.0                0.8848E 01   -0.2452E 01   -0.2452E 01    0.0
  4       0.9227D 02    0.4997D 00      0.4650D-01      0.0                0.1498E 02   -0.4047E 01   -0.4047E 01    0.0
  5       0.9474D 02    0.6273D 00      0.5837D-01      0.0                0.2153E 02   -0.5377E 01   -0.5377E 01    0.0
  6       0.9857D 02    0.7679D 00      0.7145D-01      0.0                0.2881E 02   -0.5883E 01   -0.5882E 01    0.0
  7       0.1034D 03    0.8771D 00      0.8161D-01      0.0                0.2707E 02   -0.3637E 01   -0.3636E 01    0.0
  8       0.1060D 03    0.9135D 00      0.8500D-01      0.0                0.2994E 02   -0.2756E 01   -0.2755E 01    0.0
  9       0.1097D 03    0.9285D 00      0.8640D-01      0.0                0.4689E-01   -0.1492E-02   -0.1050E-02    0.0
 10       0.1160D 03    0.9546D 00      0.8883D-01      0.0                0.5722E-01    0.3521E-02    0.4021E-02    0.0
 11       0.1214D 03    0.9763D 00      0.9084D-01      0.0                0.6339E-01    0.8531E-02    0.8963E-02    0.0
 12       0.1238D 03    0.9851D 00      0.9167D-01      0.0                0.3788E-23    0.6211E-24   -0.1151E 05    0.0
=========================================================================================================================
   MATERIAL DATA

    NAME   MATL       TOT CAP          TOT HEAT         AVG TEMP        TMELT              HMELT
    SAND     1      1.07359E 00      1.04171E 02      9.70308E 01     0.0                0.0
    STEL     2      2.82356E-01      2.99404E 01      1.06038E 02     0.0                0.0
    AIR      3      1.44246E-03      1.67498E-01      1.16120E 02     0.0                0.0
=================================================================================================================
   NODE DATA

   NODE   MATL  NTYPE    RADIUS        VOLUME         MASS          CAPACITY   CONDUCTIVITY     ZIP           SLIM
      1     1     4    0.1000E-02   0.1257E-04    0.6836D-06    0.1299D-06    0.2700D-03    0.6786D-05    0.1914D-01
      2     1     4    0.5010E 00   0.3142E 01    0.1709D 00    0.3247D-01    0.2700D-03    0.1705D-02    0.1905D 02
      3     1     4    0.1500E 01   0.9425E 01    0.5127D 00    0.9741D-01    0.2700D-03    0.5091D-02    0.1913D 02
      4     1     4    0.2500E 01   0.1571E 02    0.8545D 00    0.1624D 00    0.2700D-03    0.8482D-02    0.1914D 02
      5     1     4    0.3500E 01   0.2199E 02    0.1196D 01    0.2273D 00    0.2700D-03    0.1188D-01    0.1914D 02
      6     1     4    0.4500E 01   0.2827E 02    0.1538D 01    0.2922D 00    0.2700D-03    0.1648D-01    0.1773D 02
      7     1     4    0.5375E 01   0.2533E 02    0.1378D 01    0.2618D 00    0.2700D-03    0.3564D-01    0.7345D 01
      8     2     4    0.5875E 01   0.9228E 01    0.2590D 01    0.2824D 00    0.3640D-01    0.3247D-01    0.8695D 01
      9     3     4    0.6500E 01   0.4084E 02    0.1781D-02    0.4274D-03    0.2250D-04    0.2686D-02    0.1591D 00
     10     3     4    0.7500E 01   0.4712E 02    0.2055D-02    0.4931D-03    0.2250D-04    0.2157D-02    0.2286D 00
     11     3     4    0.8469E 01   0.4989E 02    0.2175D-02    0.5220D-03    0.2250D-04    0.3863D-02    0.1351D 00
     12     2     2    0.8938E 01   0.1000E-23    0.2807D-24    0.3060D-25    0.3640D-01    0.5616D 08    0.1000D-23
=================================================================================================================
   INTERNAL CONNECTION DATA

       NOD1  NOD2     AREA          HINT          RINT             TRAN         HEAT FLOW    AVG RATE
         1     2    0.1257D-01   0.1000E 13    0.0              0.6786D-05  -0.3383E-05  -0.3342E-08
         2     3    0.6283D 01   0.1000E 13    0.0              0.1698D-02  -0.8596E 00  -0.8491E-03
         3     4    0.1257D 02   0.1000E 13    0.0              0.3393D-02  -0.3442E 01  -0.3400E-02
         4     5    0.1885D 02   0.1000E 13    0.0              0.5089D-02  -0.7707E 01  -0.7612E-02
         5     6    0.2513D 02   0.1000E 13    0.0              0.6786D-02  -0.1338E 02  -0.1322E-01
         6     7    0.3142D 02   0.1000E 13    0.0              0.9694D-02  -0.1963E 02  -0.1939E-01
         7     8    0.3613D 02   0.1000E 13    0.0              0.2595D-01  -0.2352E 02  -0.2323E-01
         8     9    0.3770D 02   0.1000E 13    0.0              0.1696D-02  -0.2152E 01  -0.2126E-02
         8    12    0.3770D 02   0.1000E-23    0.9760E-04       0.4827D-02  -0.2430E 02  -0.2400E-01
         9    10    0.4398D 02   0.1000E 13    0.0              0.9896D-03  -0.2153E 01  -0.2127E-02
        10    11    0.5027D 02   0.1000E 13    0.0              0.1167D-02  -0.2148E 01  -0.2122E-02
        11    12    0.5616D 02   0.1000E 13    0.0              0.2695D-02  -0.2137E 01  -0.2111E-02
=================================================================================================================
   BOUNDARY NODE DATA

    NODB     TEMPB        HEAT FLOW    AVG RATE
    2001   1.2380E 02   -1.1533D 04  -1.1392E 01

   SYSTEM TOTAL         -1.1533E 04  -1.1392E 01
=================================================================================================================
   EXTERNAL CONNECTION DATA

     NODS NODSB    AREAS        HSURE        POWER          RSURE          TRANS       HEAT FLOW     AVG RATE
      12  2001   5.6156D 01   1.0000D 06   0.0            0.0           5.6156D 07  -1.1533E 04  -1.1392E 01
=================================================================================================================
```

```
TRUMP OUTPUT DATA                                                                                    DATA DECK    1

 *   MISSLE PROBLEM    ONE DIMENSIONAL
==================================================================================================================
   PRINTOUT    CYCLE   TOO FAST  TOO SLOW     KWIT     DELTMX          SMALL            TVARY       NUTS
      10        120        6         0          0    1.00000E 12    1.00000E 00     1.00000E 00     5

     TOTAL TIME     TIME STEP     HEAT FLOW     TEMP FROM FLUX   FLUX RATE       TEMP RATE
    1.18976E 03   1.34137E 01   -1.25268E 04   -9.22863E 03   -1.05289E 01   -7.75673E 00

     AVG TEMP     HEAT CAPACITY   HEAT CONTENT     GEN RATE          HEAT GEN       TEMP FROM GEN
    1.11428E 02    1.35739D 00    1.51250E 02    0.0               0.0            0.0
==================================================================================================================
 NODE         TEMP         DT           DDT          GE N RATE          W            H            F          CURE AT 280 F
   1      0.9912D 02   0.8219D 00   0.6128D-01   0.0              0.1287E-04  -0.2089E-05  -0.1987E-05    0.0
   2      0.9912D 02   0.8220D 00   0.6128D-01   0.0              0.3219E 01  -0.5254E 00  -0.5254E 00    0.0
   3      0.1003D 03   0.8439D 00   0.6291D-01   0.0              0.9771E 01  -0.1529E 01  -0.1529E 01    0.0
   4      0.1027D 03   0.8821D 00   0.6576D-01   0.0              0.1668E 02  -0.2352E 01  -0.2352E 01    0.0
   5      0.1064D 03   0.9262D 00   0.6905D-01   0.0              0.2419E 02  -0.2722E 01  -0.2722E 01    0.0
   6      0.1115D 03   0.9636D 00   0.7183D-01   0.0              0.3259E 02  -0.2098E 01  -0.2098E 01    0.0
   7      0.1173D 03   0.9814D 00   0.7316D-01   0.0              0.3070E 02  -0.1235E-01  -0.1159E-01    0.0
   8      0.1201D 03   0.9836D 00   0.7333D-01   0.0              0.3392E 02   0.1223E 01   0.1224E 01    0.0
   9      0.1237D 03   0.9652D 00   0.7196D-01   0.0              0.5286E-01   0.4482E-02   0.4870E-02    0.0
  10      0.1298D 03   0.9333D 00   0.6958D-01   0.0              0.6401E-01   0.1031E-01   0.1076E-01    0.0
  11      0.1350D 03   0.9062D 00   0.6756D-01   0.0              0.7049E-01   0.1563E-01   0.1601E-01    0.0
  12      0.1373D 03   0.8942D 00   0.6667D-01   0.0              0.4201E-23   0.1035E-23  -0.1252E 05    0.0
==================================================================================================================
   MATERIAL DATA

     NAME  MATL      TOT CAP         TOT HEAT         AVG TEMP        TMELT          HMELT
     SAND    1     1.07359E 00     1.17143E 02     1.09114E 02     0.0            0.0
     STEL    2     2.82356E-01     3.39193E 01     1.20130E 02     0.0            0.0
     AIR     3     1.44246E-03     1.87363E-01     1.29892E 02     0.0            0.0
=============================================================================================================
   NODE DATA

   NODE  MATL NTYPE    RADIUS       VOLUME        MASS        CAPACITY  CONDUCTIVITY     ZIP          SLIM
     1     1    4   0.1000E-02   0.1257E-04   0.6836D-06   0.1299D-06   0.2700D-03   0.6786D-05   0.1914D-01
     2     1    4   0.5010E 00   0.3142E 01   0.1709D 00   0.3247D-01   0.2700D-03   0.1705D-02   0.1905D 02
     3     1    4   0.1500E 01   0.9425E 01   0.5127D 00   0.9741D-01   0.2700D-03   0.5091D-02   0.1913D 02
     4     1    4   0.2500E 01   0.1571E 02   0.8545D 00   0.1624D 00   0.2700D-03   0.6482D-02   0.1914D 02
     5     1    4   0.3500E 01   0.2199E 02   0.1196D 01   0.2273D 00   0.2700D-03   0.1188D-01   0.1914D 02
     6     1    4   0.4500E 01   0.2827E 02   0.1538D 01   0.2922D 00   0.2700D-03   0.1648D-01   0.1773D 02
     7     1    4   0.5375E 01   0.2533E 02   0.1378D 01   0.2618D 00   0.2700D-03   0.3564D-01   0.7345D 01
     8     2    4   0.5875E 01   0.9228E 01   0.2590D 01   0.2824D 00   0.3640D-01   0.3283D-01   0.8601D 01
     9     3    4   0.6500E 01   0.4084E 02   0.1781D-02   0.4274D-03   0.2250D-04   0.2686D-02   0.1591D 00
    10     3    4   0.7500E 01   0.4712E 02   0.2055D-02   0.4931D-03   0.2250D-04   0.2157D-02   0.2286D 00
    11     3    4   0.8469E 01   0.4989E 02   0.2175D-02   0.5220D-03   0.2250D-04   0.3863D-02   0.1351D 00
    12     2    2   0.8938E 01   0.1000E-23   0.2807D-24   0.3060D-25   0.3640D-01   0.5616D 08   0.1000D-23
=============================================================================================================
   INTERNAL CONNECTION DATA

        NOD1   NOD2     AREA          HINT          RINT              TRAN         HEAT FLOW    AVG RATE
          1      2   0.1257D-01   0.1000E 13   0.0              0.6786D-05  -0.2162E-05  -0.1817E-08
          2      3   0.6283D 01   0.1000E 13   0.0              0.1698D-02  -0.5692E 00  -0.4784E-03
          3      4   0.1257D 02   0.1000E 13   0.0              0.3393D-02  -0.2229E 01  -0.1874E-02
          4      5   0.1885D 02   0.1000E 13   0.0              0.5089D-02  -0.4798E 01  -0.4033E-02
          5      6   0.2513D 02   0.1000E 13   0.0              0.6786D-02  -0.7819E 01  -0.6572E-02
          6      7   0.3142D 02   0.1000E 13   0.0              0.9694D-02  -0.1028E 02  -0.8640E-02
          7      8   0.3613D 02   0.1000E 13   0.0              0.2595D-01  -0.1055E 02  -0.8864E-02
          8      9   0.3770D 02   0.1000E 13   0.0              0.1696D-02  -0.1045E 01  -0.8787E-03
          8     12   0.3770D 02   0.1000E-23   0.9760E-04       0.5183D-02  -0.8456E 01  -0.7107E-02
          9     10   0.4398D 02   0.1000E 13   0.0              0.9896D-03  -0.1040E 01  -0.8744E-03
         10     11   0.5027D 02   0.1000E 13   0.0              0.1167D-02  -0.1028E 01  -0.8645E-03
         11     12   0.5616D 02   0.1000E 13   0.0              0.2695D-02  -0.1011E 01  -0.8494E-03
=============================================================================================================
   BOUNDARY NODE DATA

    NODB     TEMPB         HEAT FLOW     AVG RATE
    2001   1.3732E 02   -1.2527D 04   -1.0529E 01

   SYSTEM TOTAL          -1.2527E 04   -1.0529E 01
=============================================================================================================
   EXTERNAL CONNECTION DATA

     NODS NODSB     AREAS         HSURE        POWER          RSURE          TRANS         HEAT FLOW     AVG RATE
      12   2001   5.6156D 01   1.0000D 06   0.0             0.0           5.6156D 07  -1.2527E 04  -1.0529E 01
=============================================================================================================
   WILL REPEAT CYCLE    130      DTMAX = 3.720E 00 DTPRE = 3.720E 00 DELT = 1.552D 01 SUMTIM = 1.321E 03
   WILL REPEAT CYCLE    130      DTMAX = 2.860E 00 DTPRE = 1.860E 00 DELT = 7.762D 00 SUMTIM = 1.321E 03
```

```
   TRUMP OUTPUT DATA                                                                                DATA DECK    1

   *   MISSLE PROBLEM    ONE DIMENSIONAL
==========================================================================================================

    PRINTOUT     CYCLE    TOO FAST  TOO SLOW      KWIT      DELTMX            SMALL            TVARY        NUTS
       11         135         6         0           0    1.00000E 12      1.00000E 00      1.00000E 00      5

     TOTAL TIME      TIME STEP       HEAT FLOW     TEMP FROM FLUX   FLUX RATE       TEMP RATE
    1.33641E 03     2.96298E 00    -1.12065E 04    -8.25591E 03   -8.38547E 00    -6.17766E 00

      AVG TEMP      HEAT CAPACITY    HEAT CONTENT     GEN RATE          HEAT GEN        TEMP FROM GEN
    1.18397E 02     1.35739D 00     1.60710E 02     0.0               0.0              0.0
==========================================================================================================

 NODE          TEMP          DT            DDT          GE N RATE         W            H             F           CURE AT 280 F
   1        0.1085D 03    0.1825D 00    0.3808D-01    0.0            0.1410E-04  -0.8670E-06  -0.7665E-06   0.0
   2        0.1085D 03    0.1825D 00    0.3807D-01    0.0            0.3524E 01  -0.2200E 00  -0.2200E 00   0.0
   3        0.1097D 03    0.1761D 00    0.3673D-01    0.0            0.1069E 02  -0.6136E 00  -0.6136E 00   0.0
   4        0.1120D 03    0.1608D 00    0.3354D-01    0.0            0.1818E 02  -0.8458E 00  -0.8458E 00   0.0
   5        0.1152D 03    0.1319D 00    0.2750D-01    0.0            0.2619E 02  -0.7184E 00  -0.7183E 00   0.0
   6        0.1192D 03    0.8019D-01    0.1673D-01    0.0            0.3482E 02   0.1327E 00   0.1329E 00   0.0
   7        0.1227D 03   -0.9932D-02   -0.2072D-26    0.0            0.3212E 02   0.1410E 01   0.1411E 01   0.0
   8        0.1240D 03   -0.8645D-01   -0.1803D-01    0.0            0.3500E 02   0.2303E 01   0.2303E 01   0.0
   9        0.1249D 03   -0.2229D 00   -0.4649D-01    0.0            0.5338E-01   0.5005E-02   0.5133E-02   0.0
  10        0.1265D 03   -0.4511D 00   -0.9410D-01    0.0            0.6238E-01   0.8685E-02   0.8810E-02   0.0
  11        0.1278D 03   -0.6101D 00   -0.1273D 00    0.0            0.6672E-01   0.1186E-01   0.1195E-01   0.0
  12        0.1284D 03   -0.5863D 00   -0.1223D 00    0.0            0.3928E-23   0.7610E-24  -0.1121E 05   0.0
==========================================================================================================
   MATERIAL DATA

     NAME   MATL      TOT CAP          TOT HEAT         AVG TEMP         TMELT             HMELT
     SAND     1     1.07359E 00      1.25528E 02      1.16924E 02      0.0               0.0
     STEL     2     2.82356E-01      3.49993E 01      1.23955E 02      0.0               0.0
     AIR      3     1.44246E-03      1.82483E-01      1.26509E 02      0.0               0.0
   =======================================================================================================
   NODE DATA

   NODE   MATL NTYPE    RADIUS         VOLUME          MASS         CAPACITY   CONDUCTIVITY     ZIP           SLIM
      1     1     4    0.1000E-02    0.1257E-04    0.6836D-06    0.1299D-06    0.2700D-03    0.6786D-05    0.1914D-01
      2     1     4    0.5010E 00    0.3142E 01    0.1709D 00    0.3247D-01    0.2700D-03    0.1705D-02    0.1905D 02
      3     1     4    0.1500E 01    0.9425E 01    0.5127D 00    0.9741D-01    0.2700D-03    0.5091D-02    0.1913D 02
      4     1     4    0.2500E 01    0.1571E 02    0.8545D 00    0.1624D 00    0.2700D-03    0.8482D-02    0.1914D 02
      5     1     4    0.3500E 01    0.2199E 02    0.1196D 01    0.2273D 00    0.2700D-03    0.1188D-01    0.1914D 02
      6     1     4    0.4500E 01    0.2827E 02    0.1538D 01    0.2922D 00    0.2700D-03    0.1648D-01    0.1773D 02
      7     1     4    0.5375E 01    0.2533E 02    0.1378D 01    0.2618D 00    0.2700D-03    0.3564D-01    0.7345D 01
      8     2     4    0.5875E 01    0.9228E 01    0.2590D 01    0.2824D 00    0.3640D-01    0.3278D-01    0.8614D 01
      9     3     4    0.6500E 01    0.4084E 02    0.1781D-02    0.4274D-03    0.2250D-04    0.2686D-02    0.1591D 00
     10     3     4    0.7500E 01    0.4712E 02    0.2055D-02    0.4931D-03    0.2250D-04    0.2157D-02    0.2286D 00
     11     3     4    0.8469E 01    0.4989E 02    0.2175D-02    0.5220D-03    0.2250D-04    0.3863D-02    0.1351D 00
     12     2     2    0.8938E 01    0.1000E-23    0.2807D-24    0.3060D-25    0.3640D-01    0.5616D 08    0.1000D-23
   =======================================================================================================
   INTERNAL CONNECTION DATA

       NOD1  NOD2     AREA          HINT         RINT             TRAN        HEAT FLOW     AVG RATE
          1     2   0.1257D-01   0.1000E 13   0.0             0.6786D-05  -0.7533E-06  -0.5637E-09
          2     3   0.6283D 01   0.1000E 13   0.0             0.1698D-02  -0.2167E 00  -0.1621E-03
          3     4   0.1257D 02   0.1000E 13   0.0             0.3393D-02  -0.8244E 00  -0.6169E-03
          4     5   0.1885D 02   0.1000E 13   0.0             0.5089D-02  -0.1677E 01  -0.1255E-02
          5     6   0.2513D 02   0.1000E 13   0.0             0.6786D-02  -0.2449E 01  -0.1833E-02
          6     7   0.3142D 02   0.1000E 13   0.0             0.9694D-02  -0.2473E 01  -0.1851E-02
          7     8   0.3613D 02   0.1000E 13   0.0             0.2595D-01  -0.1288E 01  -0.9638E-03
          8     9   0.3770D 02   0.1000E 13   0.0             0.1696D-02  -0.3923E 00  -0.2935E-03
          8    12   0.3770D 02   0.1000E-23   0.9760E-04      0.5134D-02   0.1110E 01   0.8306E-03
          9    10   0.4398D 02   0.1000E 13   0.0             0.9896D-03  -0.3877E 00  -0.2901E-03
         10    11   0.5027D 02   0.1000E 13   0.0             0.1167D-02  -0.3797E 00  -0.2841E-03
         11    12   0.5616D 02   0.1000E 13   0.0             0.2695D-02  -0.3688E 00  -0.2759E-03
   =======================================================================================================
   BOUNDARY NODE DATA

    NODB     TEMPB         HEAT FLOW     AVG RATE
    2001   1.2832E 02   -1.1207D 04   -8.3856E 00

   SYSTEM TOTAL            -1.1207E 04   -8.3856E 00
   =======================================================================================================
   EXTERNAL CONNECTION DATA

     NODS NODSB     AREAS        HSURE         POWER          RSURE          TRANS        HEAT FLOW     AVG RATE
       12  2001   5.6156D 01   1.00000D 06   0.0            0.0            5.6156D 07  -1.1206E 04  -8.3855E 00
   =======================================================================================================
```

```
TRUMP OUTPUT DATA                                                                          DATA DECK    1
 *   MISSLE PROBLEM    ONE DIMENSIONAL
=========================================================================================================
  PRINTOUT     CYCLE   TOO FAST  TOO SLOW     KWIT     DELTMX          SMALL           IVARY       NUTS
     12         150        6         0          0    1.00000E 12   1.00000E 00    1.00000E 00      4

   TOTAL TIME      TIME STEP       HEAT FLOW    TEMP FROM FLUX   FLUX RATE       TEMP RATE
  1.39691E 03    4.16768E 00    3.74844E 03     2.76152E 03    2.68338E 00     1.97688E 00

   AVG TEMP     HEAT CAPACITY   HEAT CONTENT    GEN RATE        HEAT GEN      TEMP FROM GEN
  1.18103E 02    1.35739D 00    1.60311E 02    0.0             0.0            0.0
=========================================================================================================
 NODE         TEMP         DT           DDT         GE N RATE         W            H            F         CURE AT 280 F
   1       0.1120D 03   0.2142D 00   0.5140D-01   0.0           0.1454E-04  -0.4205E-06  -0.3209E-06   0.0
   2       0.1120D 03   0.2142D 00   0.5140D-01   0.0           0.3636E 01  -0.1083E 00  -0.1083E 00   0.0
   3       0.1129D 03   0.1950D 00   0.4679D-01   0.0           0.1100E 02  -0.2982E 00  -0.2982E 00   0.0
   4       0.1148D 03   0.1500D 00   0.3599D-01   0.0           0.1863E 02  -0.3971E 00  -0.3970E 00   0.0
   5       0.1171D 03   0.6560D-01   0.1574D-01   0.0           0.2661E 02  -0.2979E 00  -0.2978E 00   0.0
   6       0.1193D 03  -0.7702D-01  -0.1848D-01   0.0           0.3487E 02   0.1852E 00   0.1854E 00   0.0
   7       0.1203D 03  -0.2649D 00  -0.6356D-01   0.0           0.3150E 02   0.7880E 00   0.7884E 00   0.0
   8       0.1200D 03  -0.3632D 00  -0.8714D-01   0.0           0.3389E 02   0.1192E 01   0.1192E 01   0.0
   9       0.1188D 03  -0.4940D 00  -0.1185D 00   0.0           0.5076E-01   0.2387E-02   0.2391E-02   0.0
  10       0.1166D 03  -0.7209D 00  -0.1730D 00   0.0           0.5750E-01   0.3803E-02   0.3788E-02   0.0
  11       0.1147D 03  -0.9138D 00  -0.2193D 00   0.0           0.5987E-01   0.5009E-02   0.4977E-02   0.0
  12       0.1138D 03  -0.1000D 01  -0.2400D 00   0.0           0.3483E-23   0.3158E-24   0.3747E 04   0.0
=========================================================================================================
   MATERIAL DATA

    NAME  MATL       TOT CAP         TOT HEAT        AVG TEMP        TMELT            HMELT
    SAND    1      1.07359E 00     1.26255E 02     1.17601E 02     0.0              0.0
    STEL    2      2.82356E-01     3.38886E 01     1.20021E 02     0.0              0.0
    AIR     3      1.44246E-03     1.68137E-01     1.16563E 02     0.0              0.0
=========================================================================================================
   NODE DATA

   NODE  MATL NTYPE    RADIUS       VOLUME        MASS       CAPACITY   CONDUCTIVITY     ZIP          SLIM
     1     1     4   0.1000E-02   0.1257E-04   0.6836D-06   0.1299D-06   0.2700D-03   0.6786D-05   0.1914D-01
     2     1     4   0.5010E 00   0.3142E 01   0.1709D 00   0.3247D-01   0.2700D-03   0.1705D-02   0.1905D 02
     3     1     4   0.1500E 01   0.9425E 01   0.5127D 00   0.9741D-01   0.2700D-03   0.5091D-02   0.1913D 02
     4     1     4   0.2500E 01   0.1571E 02   0.8545D 00   0.1624D 00   0.2700D-03   0.8482D-02   0.1914D 02
     5     1     4   0.3500E 01   0.2199E 02   0.1196D 01   0.2273D 00   0.2700D-03   0.1188D-01   0.1914D 02
     6     1     4   0.4500E 01   0.2827E 02   0.1538D 01   0.2922D 00   0.2700D-03   0.1648D-01   0.1773D 02
     7     1     4   0.5375E 01   0.2533E 02   0.1378D 01   0.2618D 00   0.2700D-03   0.3564D-01   0.7345D 01
     8     2     4   0.5875E 01   0.9228E 01   0.2590D 01   0.2824D 00   0.3640D-01   0.3254D-01   0.8677D 01
     9     3     4   0.6500E 01   0.4084E 02   0.1781D-02   0.4274D-03   0.2250D-04   0.2686D-02   0.1591D 00
    10     3     4   0.7500E 01   0.4712E 02   0.2055D-02   0.4931D-03   0.2250D-04   0.2157D-02   0.2286D 00
    11     3     4   0.8469E 01   0.4989E 02   0.2175D-02   0.5220D-03   0.2250D-04   0.3863D-02   0.1351D 00
    12     2     2   0.8938E 01   0.1000E-23   0.2807D-24   0.3060D-25   0.3640D-01   0.5616D 08   0.1000D-23
=========================================================================================================
   INTERNAL CONNECTION DATA

       NOD1   NOD2     AREA         HINT        RINT              TRAN        HEAT FLOW    AVG RATE
          1      2   0.1257D-01   0.1000E 13   0.0              0.6786D-05  -0.3077E-06  -0.2203E-09
          2      3   0.6283D 01   0.1000E 13   0.0              0.1698D-02  -0.1051E 00  -0.7521E-04
          3      4   0.1257D 02   0.1000E 13   0.0              0.3393D-02  -0.3974E 00  -0.2845E-03
          4      5   0.1885D 02   0.1000E 13   0.0              0.5089D-02  -0.8014E 00  -0.5737E-03
          5      6   0.2513D 02   0.1000E 13   0.0              0.6786D-02  -0.1153E 01  -0.8254E-03
          6      7   0.3142D 02   0.1000E 13   0.0              0.9694D-02  -0.1125E 01  -0.8050E-03
          7      8   0.3613D 02   0.1000E 13   0.0              0.2595D-01  -0.5618E 00  -0.4022E-03
          8      9   0.3770D 02   0.1000E 13   0.0              0.1696D-02  -0.4136E 00  -0.2960E-03
          8     12   0.3770D 02   0.1000E-23   0.9760E-04       0.4895D-02   0.7466E 00   0.5345E-03
          9     10   0.4398D 02   0.1000E 13   0.0              0.9896D-03  -0.4117E 00  -0.2947E-03
         10     11   0.5027D 02   0.1000E 13   0.0              0.1167D-02  -0.4087E 00  -0.2926E-03
         11     12   0.5616D 02   0.1000E 13   0.0              0.2695D-02  -0.4048E 00  -0.2898E-03
=========================================================================================================
   BOUNDARY NODE DATA

    NODB     TEMPB         HEAT FLOW    AVG RATE
    2001   1.1382E 02    3.7483D 03   2.6833E 00

   SYSTEM TOTAL          3.7483E 03   2.6833E 00
=========================================================================================================
   EXTERNAL CONNECTION DATA

    NODS NODSB     AREAS        HSURE         POWER        RSURE         TRANS        HEAT FLOW    AVG RATE
     12  2001   5.6156D 01   1.0000D 06   0.0           0.0           5.6156D 07   3.7484E 03   2.6834E 00
=========================================================================================================
```

```
TRUMP OUTPUT DATA                                                                               DATA DECK    1

  *   MISSLE PROBLEM    ONE DIMENSIONAL
==============================================================================================================

   PRINTOUT    CYCLE   TOO FAST  TOO SLOW     KWIT     DELTMX          SMALL            TVARY         NUTS
      13        161        6         0          1    1.00000E 12    1.00000E 00     1.00000E 00       2

    TOTAL TIME      TIME STEP      HEAT FLOW    TEMP FROM FLUX   FLUX RATE      TEMP RATE
   1.44000E 03     1.37476E 00    3.93701E 03    2.90044E 03    2.73404E 00    2.01419E 00

    AVG TEMP     HEAT CAPACITY   HEAT CONTENT    GEN RATE        HEAT GEN       TEMP FROM GEN
   1.16574E 02    1.35739D 00    1.58236E 02    0.0             0.0             0.0
==============================================================================================================

NODE        TEMP          DT            DDT        GE N RATE        W           H             F         CURE AT 280 F
  1     0.1139D 03   0.5220D-01    0.1317D-01    0.0          0.1479E-04  -0.1703E-06  -0.7515E-07   0.0
  2     0.1139D 03   0.5219D-01    0.1317D-01    0.0          0.3698E 01  -0.4582E-01  -0.4581E-01   0.0
  3     0.1146D 03   0.4274D-01    0.1078D-01    0.0          0.1116E 02  -0.1353E 00  -0.1353E 00   0.0
  4     0.1159D 03   0.2215D-01    0.5588D-02    0.0          0.1881E 02  -0.2179E 00  -0.2178E 00   0.0
  5     0.1172D 03  -0.1228D-01   -0.3097D-02    0.0          0.2664E 02  -0.2740E 00  -0.2739E 00   0.0
  6     0.1179D 03  -0.6267D-01   -0.1581D-01    0.0          0.3445E 02  -0.2376E 00  -0.2374E 00   0.0
  7     0.1170D 03  -0.1200D 00   -0.3027D-01    0.0          0.3063E 02  -0.8161E-01  -0.8120E-01   0.0
  8     0.1158D 03  -0.1474D 00   -0.3718D-01    0.0          0.3269E 02  -0.8683E-02  -0.8354E-02   0.0
  9     0.1133D 03  -0.1857D 00   -0.4684D-01    0.0          0.4841E-01   0.3003E-04   0.1120E-04   0.0
 10     0.1089D 03  -0.2509D 00   -0.6330D-01    0.0          0.5371E-01   0.1395E-04  -0.2717E-04   0.0
 11     0.1052D 03  -0.3058D 00   -0.7715D-01    0.0          0.5490E-01   0.3688E-04  -0.1916E-04   0.0
 12     0.1035D 03  -0.3293D 00   -0.8307D-01    0.0          0.3167E-23   0.1252E-29   0.3938E 04   0.0
==============================================================================================================
   MATERIAL DATA

    NAME   MATL      TOT CAP          TOT HEAT        AVG TEMP        TMELT           HMELT
    SAND     1     1.07359E 00     1.25391E 02     1.16796E 02     0.0             0.0
    STEL     2     2.82356E-01     3.26880E 01     1.15769E 02     0.0             0.0
    AIR      3     1.44246E-03     1.57018E-01     1.08855E 02     0.0             0.0
=========================================================================================================
   NODE DATA

   NODE  MATL NTYPE   RADIUS       VOLUME        MASS         CAPACITY   CONDUCTIVITY     ZIP          SLIM
     1     1    4   0.1000E-02  0.1257E-04  0.6836D-06   0.1299D-06  0.2700D-03   0.6786D-05  0.1914D-01
     2     1    4   0.5010E 00  0.3142E 01  0.1709D 00   0.3247D-01  0.2700D-03   0.1705D-02  0.1905D 02
     3     1    4   0.1500E 01  0.9425E 01  0.5127D 00   0.9741D-01  0.2700D-03   0.5091D-02  0.1913D 02
     4     1    4   0.2500E 01  0.1571E 02  0.8545D 00   0.1624D 00  0.2700D-03   0.8482D-02  0.1914D 02
     5     1    4   0.3500E 01  0.2199E 02  0.1196D 01   0.2273D 00  0.2700D-03   0.1188D-01  0.1914D 02
     6     1    4   0.4500E 01  0.2827E 02  0.1538D 01   0.2922D 00  0.2700D-03   0.1648D-01  0.1773D 02
     7     1    4   0.5375E 01  0.2533E 02  0.1378D 01   0.2618D 00  0.2700D-03   0.3564D-01  0.7345D 01
     8     2    4   0.5875E 01  0.9228E 01  0.2590D 01   0.2824D 00  0.3640D-01   0.3235D-01  0.8728D 01
     9     3    4   0.6500E 01  0.4084E 02  0.1781D-02   0.4274D-03  0.2250D-04   0.2686D-02  0.1591D 00
    10     3    4   0.7500E 01  0.4712E 02  0.2055D-02   0.4931D-03  0.2250D-04   0.2157D-02  0.2286D 00
    11     3    4   0.8469E 01  0.4989E 02  0.2175D-02   0.5220D-03  0.2250D-04   0.3863D-02  0.1351D 00
    12     2    2   0.8938E 01  0.1000E-23  0.2807D-24   0.3060D-25  0.3640D-01   0.5616D 08  0.1000D-23
=========================================================================================================
   INTERNAL CONNECTION DATA

       NOD1   NOD2      AREA         HINT          RINT            TRAN        HEAT FLOW     AVG RATE
         1      2    0.1257D-01   0.1000E 13   0.0             0.6786D-05  -0.6199E-07  -0.4305E-10
         2      3    0.6283D 01   0.1000E 13   0.0             0.1698D-02  -0.4255E-01  -0.2955E-04
         3      4    0.1257D 02   0.1000E 13   0.0             0.3393D-02  -0.1720E 00  -0.1194E-03
         4      5    0.1885D 02   0.1000E 13   0.0             0.5089D-02  -0.3967E 00  -0.2755E-03
         5      6    0.2513D 02   0.1000F 13   0.0             0.6786D-02  -0.7245E 00  -0.5031E-03
         6      7    0.3142D 02   0.1000E 13   0.0             0.9694D-02  -0.1119E 01  -0.7769E-03
         7      8    0.3613D 02   0.1000E 13   0.0             0.2595D-01  -0.1426E 01  -0.9901E-03
         8      9    0.3770D 02   0.1000E 13   0.0             0.1696D-02  -0.5517E 00  -0.3831E-03
         8     12    0.3770D 02   0.1000E-23   0.9760E-04      0.4707D-02  -0.1180E 01  -0.8192E-03
         9     10    0.4398D 02   0.1000E 13   0.0             0.9896D-03  -0.5522E 00  -0.3835E-03
        10     11    0.5027D 02   0.1000E 13   0.0             0.1167D-02  -0.5531E 00  -0.3841E-03
        11     12    0.5616D 02   0.1000E 13   0.0             0.2695D-02  -0.5541E 00  -0.3848E-03
=========================================================================================================
   BOUNDARY NODE DATA

    NODB     TEMPB         HEAT FLOW     AVG RATE
    2001   1.0350E 02    3.9369D 03    2.7339E 00

   SYSTEM TOTAL           3.9369E 03    2.7339E 00
=========================================================================================================
   FXTERNAL CONNECTION DATA

     NODS NODSB     AREAS        HSURE        POWER          RSURE          TRANS       HEAT FLOW     AVG RATE
       12  2001   5.6156D 01  1.00000 06   0.0            0.0            5.6156D 07  3.9370E 03  2.7340E 00
=========================================================================================================
   TOTAL NUMBER OF ITERATIONS =   1102      MAX =     16
   ENDED PROB    1      KCYC =    161      KWIT =  1      S UMTIM = 0.14400E 04
```

```
//WIR71687 JOB (1687,0860FT,NF12),'WIRZBURGER.A. BOX W',TIME=(4,00)
//JOBLIB       DD  UNIT=2321,DSNAME=S1734.KATZ,
//     DISP=(OLD,PASS),VOLUME=SER=CEL001
//  EXEC    PGM=TRUMP,REGION=350K
//FT06F001     DD  SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=3325),
//      SPACE=(CYL,(6,1))
//FT05F001     DD  *

*   MISSLE PROBLEM    TWO DIMENSIONAL

BLOCK 1   CONTROLS, LIMITS, CONSTANTS
    5       1
    2   3          1.000 E 00 1.000E 00  1380.0   8000.0
 114.0

BLOCK 2     MATERIAL NAMES, NUMBERS, THERMAL PROPERTIES.
ASAND     1                    0.0544      0.19       0.00027
ASTEL     2                    0.2807      0.109      0.0364
AAIR      3                    0.0000436   0.240      0.0000225

BLOCK 4   NODE NUMBERS, MATERIAL REFERENCES, TYPES, VOLUMES.
    1     3   12    1          0.25        0.002      0.001
    2     3   12    1          0.25        0.998      0.501
    3     3   12    1          0.25        1.00       1.50
    4     3   12    1          0.25        1.00       2.50
    5     3   12    1          0.25        1.00       3.50
    6     3   12    1          0.25        1.00       4.50
    7     3   12    1          0.25        0.75       5.375
    8     3   12    2          0.25        0.25       5.875
    9     3   12    3          0.25        1.00       6.50
   10     3   12    3          0.25        1.00       7.50
   11     3   12    3          0.25        0.9375     8.46875
   12     3   12    2          0.0         0.0        8.9375

BLOCK 5   INTERNAL THERMAL CONNECTION NODE NUMBERS.
    1     2   3 12 12 0.001       0.499       0.25       0.002
    2     3   3 12 12 0.499       0.500       0.25       1.00
    3     4   3 12 12 0.500       0.500       0.25       2.00
    4     5   3 12 12 0.500       0.500       0.25       3.00
    5     6   3 12 12 0.500       0.500       0.25       4.00
    6     7   3 12 12 0.500       0.375       0.25       5.00
    7     8   3 12 12 0.375       0.125       0.25       5.75
    8     9   3 12 12 0.125       0.500       0.25       6.00
    8    12   3 12 12 0.125       0.0         0.25       6.00              0.00008478
    9    10   3 12 12 0.500       0.500       0.25       7.00
   10    11   3 12 12 0.500       0.46875     0.25       8.00
   11    12   3 12 12 0.46875     0.0         0.25       8.9375
    1    37           0.000785    0.000785    0.25       0.001273
```

```
  2   38            0.393      0.393      0.25      0.635
  3   39            1.178      1.178      0.25      0.637
  4   40            1.9635     1.9635     0.25      0.637
  5   41            2.7489     2.7489     0.25      0.637
  6   42            3.534      3.534      0.25      0.637
  7   43            4.271      4.271      0.25      0.557
  8   44            4.663      4.663      0.25      0.0796
  9   45            5.105      5.105      0.25      0.637
 10   46            5.8905     5.8905     0.25      0.637
 11   47            6.651      6.651      0.25      0.597
  8   48            0.0625     0.0        0.25      6.000                    0.00000729
 32   24            0.0625     0.0        0.25      6.000                    0.00000729
 20   12            0.0625     0.0        0.25      6.000                    0.00000729
 44   12            0.0625     0.0        0.25      6.000                    0.00000729
 44   36            0.0625     0.0        0.25      6.000                    0.00000729
  1   13  2 12 12   0.000785   0.000785   0.25      0.001273
  2   14  2 12 12   0.393      0.393      0.25      0.635
  3   15  2 12 12   1.178      1.178      0.25      0.637
  4   16  2 12 12   1.9635     1.9635     0.25      0.637
  5   17  2 12 12   2.7489     2.7489     0.25      0.637
  6   18  2 12 12   3.534      3.534      0.25      0.637
  7   19  2 12 12   4.271      4.271      0.25      0.557
  8   20  2 12 12   4.663      4.663      0.25      0.0796
  9   21  2 12 12   5.105      5.105      0.25      0.637
 10   22  2 12 12   5.8905     5.8905     0.25      0.637
 11   23  2 12 12   6.651      6.651      0.25      0.597
  8   24  2 12 12   0.0625     0.0        0.25      6.00                     0.00000729

BLOCK 6   EXTERNAL THERMAL CONNECTIONS
   12 2001     3   12    1        0.25       8.9375    1.00   E6

BLOCK 7    BOUNDARY TEMPERATURE VARIATION.
  2001  100            109.5        1440.0 46.5      1380.0
  2002  100            109.0        1440.0 43.0      1284.0
  2003  100             96.0        1440.0 25.0      1212.0
  2004  100            102.5        1440.0 29.5      1284.0

ENDED-1     LAST CARD OF DATA DECK
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INPUT UNIT =    5.  OUTPUT UNIT =     6.
==========================================================================================
DATA BLOCK  10                       CONTROLS, LIMITS, CONSTANTS

IPRINT   NUM KDATA KSPEC  MCYC  MSEC NPUNCH NDOT IRITE                          SCALE
  20       0     1     0 30000 30000     0     0     0                        0.10000E 01

  KD   KT      DELTO        SMALL        TVARY        TAU           TIMAX        TMIN        TMAX,
   2    3  1.00000E 12  1.00000E 00  1.00000E 00  0.0          1.44000E 03 -1.00000E 12  1.00000E 12

   KD KSYM    GEOM        SIGMA        TBASE
   2    1  6.28319D 00  1.73000E-09  4.60000E 02

   TONE        ALONE        BONE         GONE         FONE         HONE         RONE         PONE
 1.1400E 02  0.0          0.0          0.0          0.0          0.0          0.0          0.0
==========================================================================================
DATA BLOCK  20                        MATERIAL NAMES, NUMBERS, THERMAL PROPERTIES.

NAME MATL INDEX   KA   KB LTABC LTABK    DENSITY      CAPACITY    CONDUCTIVITY   TMELT        HMELT
 SAND    1     1    0    0     0     0   5.4400E-02   1.9000E-01   2.7000E-04   0.0          0.0
 STEL    2     2    0    0     0     0   2.8070E-01   1.0900E-01   3.6400E-02   0.0          0.0
 AIR     3     3    0    0     0     0   4.3600E-05   2.4000E-01   2.2500E-05   0.0          0.0
==========================================================================================
DATA BLOCK  40                       NODE NUMBERS, MATERIAL REFERENCES, TYPES, VOLUMES.

  NODE  INDEX  MATL  NTYPE,       DLONG          DWIDE          DRAD           VOLUME
     1     1     1      0       2.50000E-01    2.00000E-03    1.00000E-03    3.14159E-06
    13     2     1      0       2.50000E-01    2.00000E-03    1.00000E-03    3.14159E-06
    25     3     1      0       2.50000E-01    2.00000E-03    1.00000E-03    3.14159E-06
    37     4     1      0       2.50000E-01    2.00000E-03    1.00000E-03    3.14159E-06
     2     5     1      0       2.50000E-01    9.98000E-01    5.01000E-01    7.85395E-01
    14     6     1      0       2.50000E-01    9.98000E-01    5.01000E-01    7.85395E-01
    26     7     1      0       2.50000E-01    9.98000E-01    5.01000E-01    7.85395E-01
    38     8     1      0       2.50000E-01    9.98000E-01    5.01000E-01    7.85395E-01
     3     9     1      0       2.50000E-01    1.00000E 00    1.50000E 00    2.35619E 00
    15    10     1      0       2.50000E-01    1.00000E 00    1.50000E 00    2.35619E 00
    27    11     1      0       2.50000E-01    1.00000E 00    1.50000E 00    2.35619E 00
    39    12     1      0       2.50000E-01    1.00000E 00    1.50000E 00    2.35619E 00
     4    13     1      0       2.50000E-01    1.00000E 00    2.50000E 00    3.92699E 00
    16    14     1      0       2.50000E-01    1.00000E 00    2.50000E 00    3.92699E 00
    28    15     1      0       2.50000E-01    1.00000E 00    2.50000E 00    3.92699E 00
    40    16     1      0       2.50000E-01    1.00000E 00    2.50000E 00    3.92699E 00
     5    17     1      0       2.50000E-01    1.00000E 00    3.50000E 00    5.49779E 00
    17    18     1      0       2.50000E-01    1.00000E 00    3.50000E 00    5.49779E 00
    29    19     1      0       2.50000E-01    1.00000E 00    3.50000E 00    5.49779E 00
    41    20     1      0       2.50000E-01    1.00000E 00    3.50000E 00    5.49779E 00
     6    21     1      0       2.50000E-01    1.00000E 00    4.50000E 00    7.06858E 00
    18    22     1      0       2.50000E-01    1.00000E 00    4.50000E 00    7.06858E 00
    30    23     1      0       2.50000E-01    1.00000E 00    4.50000E 00    7.06858E 00
    42    24     1      0       2.50000E-01    1.00000E 00    4.50000E 00    7.06858E 00
     7    25     1      0       2.50000E-01    7.50000E-01    5.37500E 00    6.33227E 00
    19    26     1      0       2.50000E-01    7.50000E-01    5.37500E 00    6.33227E 00
    31    27     1      0       2.50000E-01    7.50000E-01    5.37500E 00    6.33227E 00
    43    28     1      0       2.50000E-01    7.50000E-01    5.37500E 00    6.33227E 00
     8    29     2      0       2.50000E-01    2.50000E-01    5.87500E 00    2.30711E 00
    20    30     2      0       2.50000E-01    2.50000E-01    5.87500E 00    2.30711E 00
    32    31     2      0       2.50000E-01    2.50000E-01    5.87500E 00    2.30711E 00
    44    32     2      0       2.50000E-01    2.50000E-01    5.87500E 00    2.30711E 00
     9    33     3      0       2.50000E-01    1.00000E 00    6.50000E 00    1.02102E 01
    21    34     3      0       2.50000E-01    1.00000E 00    6.50000E 00    1.02102E 01
    33    35     3      0       2.50000E-01    1.00000E 00    6.50000E 00    1.02102E 01
    45    36     3      0       2.50000E-01    1.00000E 00    6.50000E 00    1.02102E 01
    10    37     3      0       2.50000E-01    1.00000E 00    7.50000E 00    1.17810E 01
    22    38     3      0       2.50000E-01    1.00000E 00    7.50000E 00    1.17810E 01
    34    39     3      0       2.50000E-01    1.00000E 00    7.50000E 00    1.17810E 01
    46    40     3      0       2.50000E-01    1.00000E 00    7.50000E 00    1.17810E 01
    11    41     3      0       2.50000E-01    9.37500E-01    8.46875E 00    1.24713E 01
    23    42     3      0       2.50000E-01    9.37500E-01    8.46875E 00    1.24713E 01
    35    43     3      0       2.50000E-01    9.37500E-01    8.46875E 00    1.24713E 01
    47    44     3      0       2.50000E-01    9.37500E-01    8.46875E 00    1.24713E 01
    12    45     2      2       0.0            0.0            8.93750E 00    1.00000E-24
    24    46     2      2       0.0            0.0            8.93750E 00    1.00000E-24
    36    47     2      2       0.0            0.0            8.93750E 00    1.00000E-24
    48    48     2      2       0.0            0.0            8.93750E 00    1.00000E-24
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DATA BLOCK   50                    INTERNAL THERMAL CONNECTION NODE NUMBERS.

NOD1 NOD2 INDEX   DEL1         DEL2          DLONG         DRAD          HINT          RINT          AREA
  1    2    1   1.0000D-03   4.9900D-01   2.5000E-01   2.0000E-03   1.0000E 12   0.0          3.1416D-03
 13   14    2   1.0000D-03   4.9900D-01   2.5000E-01   2.0000E-03   1.0000E 12   0.0          3.1416D-03
 25   26    3   1.0000D-03   4.9900D-01   2.5000E-01   2.0000E-03   1.0000E 12   0.0          3.1416D-03
 37   38    4   1.0000D-03   4.9900D-01   2.5000E-01   2.0000E-03   1.0000E 12   0.0          3.1416D-03
  2    3    5   4.9900D-01   5.0000D-01   2.5000E-01   1.0000E 00   1.0000E 12   0.0          1.5708D 00
 14   15    6   4.9900D-01   5.0000D-01   2.5000E-01   1.0000E 00   1.0000E 12   0.0          1.5708D 00
 26   27    7   4.9900D-01   5.0000D-01   2.5000E-01   1.0000E 00   1.0000E 12   0.0          1.5708D 00
 38   39    8   4.9900D-01   5.0000D-01   2.5000E-01   1.0000E 00   1.0000E 12   0.0          1.5708D 00
  3    4    9   5.0000D-01   5.0000D-01   2.5000E-01   2.0000E 00   1.0000E 12   0.0          3.1416D 00
 15   16   10   5.0000D-01   5.0000D-01   2.5000E-01   2.0000E 00   1.0000E 12   0.0          3.1416D 00
 27   28   11   5.0000D-01   5.0000D-01   2.5000E-01   2.0000E 00   1.0000E 12   0.0          3.1416D 00
 39   40   12   5.0000D-01   5.0000D-01   2.5000E-01   2.0000E 00   1.0000E 12   0.0          3.1416D 00
  4    5   13   5.0000D-01   5.0000D-01   2.5000E-01   3.0000E 00   1.0000E 12   0.0          4.7124D 00
 16   17   14   5.0000D-01   5.0000D-01   2.5000E-01   3.0000E 00   1.0000E 12   0.0          4.7124D 00
 28   29   15   5.0000D-01   5.0000D-01   2.5000E-01   3.0000E 00   1.0000E 12   0.0          4.7124D 00
 40   41   16   5.0000D-01   5.0000D-01   2.5000E-01   3.0000E 00   1.0000E 12   0.0          4.7124D 00
  5    6   17   5.0000D-01   5.0000D-01   2.5000E-01   4.0000E 00   1.0000E 12   0.0          6.2832D 00
 17   18   18   5.0000D-01   5.0000D-01   2.5000E-01   4.0000E 00   1.0000E 12   0.0          6.2832D 00
 29   30   19   5.0000D-01   5.0000D-01   2.5000E-01   4.0000E 00   1.0000E 12   0.0          6.2832D 00
 41   42   20   5.0000D-01   5.0000D-01   2.5000E-01   4.0000E 00   1.0000E 12   0.0          6.2832D 00
  6    7   21   5.0000D-01   3.7500D-01   2.5000E-01   5.0000E 00   1.0000E 12   0.0          7.8540D 00
 18   19   22   5.0000D-01   3.7500D-01   2.5000E-01   5.0000E 00   1.0000E 12   0.0          7.8540D 00
 30   31   23   5.0000D-01   3.7500D-01   2.5000E-01   5.0000E 00   1.0000E 12   0.0          7.3540D 00
 42   43   24   5.0000D-01   3.7500D-01   2.5000E-01   5.0000E 00   1.0000E 12   0.0          7.8540D 00
  7    8   25   3.7500D-01   1.2500D-01   2.5000E-01   5.7500E 00   1.0000E 12   0.0          9.0321D 00
 19   20   26   3.7500D-01   1.2500D-01   2.5000E-01   5.7500E 00   1.0000E 12   0.0          9.0321D 00
 31   32   27   3.7500D-01   1.2500D-01   2.5000E-01   5.7500E 00   1.0000E 12   0.0          9.0321D 00
 43   44   28   3.7500D-01   1.2500D-01   2.5000E-01   5.7500E 00   1.0000E 12   0.0          9.0321D 00
  8    9   29   1.2500D-01   5.0000D-01   2.5000E-01   6.0000E 00   1.0000E 12   0.0          9.4248D 00
 20   21   30   1.2500D-01   5.0000D-01   2.5000E-01   6.0000E 00   1.0000E 12   0.0          9.4248D 00
 32   33   31   1.2500D-01   5.0000D-01   2.5000E-01   6.0000E 00   1.0000E 12   0.0          9.4248D 00
 44   45   32   1.2500D-01   5.0000D-01   2.5000E-01   6.0000E 00   1.0000E 12   0.0          9.4248D 00
  8   12   33   1.2500D-01   0.0          2.5000E-01   6.0000E 00   1.0000E-24   8.4780E-05   9.4248D 00
 20   24   34   1.2500D-01   0.0          2.5000E-01   6.0000E 00   1.0000E-24   8.4780E-05   9.4248D 00
 32   36   35   1.2500D-01   0.0          2.5000E-01   6.0000E 00   1.0000E-24   8.4780E-05   9.4248D 00
 44   48   36   1.2500D-01   0.0          2.5000E-01   6.0000E 00   1.0000E-24   8.4780E-05   9.4248D 00
  9   10   37   5.0000D-01   5.0000D-01   2.5000E-01   7.0000E 00   1.0000E 12   0.0          1.0996D 01
 21   22   38   5.0000D-01   5.0000D-01   2.5000E-01   7.0000E 00   1.0000E 12   0.0          1.0996D 01
 33   34   39   5.0000D-01   5.0000D-01   2.5000E-01   7.0000E 00   1.0000E 12   0.0          1.0996D 01
 45   46   40   5.0000D-01   5.0000D-01   2.5000E-01   7.0000E 00   1.0000E 12   0.0          1.0996D 01
 10   11   41   5.0000D-01   4.6875D-01   2.5000E-01   8.0000E 00   1.0000E 12   0.0          1.2566D 01
 22   23   42   5.0000D-01   4.6875D-01   2.5000E-01   8.0000E 00   1.0000E 12   0.0          1.2566D 01
 34   35   43   5.0000D-01   4.6875D-01   2.5000E-01   8.0000E 00   1.0000E 12   0.0          1.2566D 01
 46   47   44   5.0000D-01   4.6875D-01   2.5000E-01   8.0000E 00   1.0000E 12   0.0          1.2566D 01
 11   12   45   4.6875D-01   0.0          2.5000E-01   8.9375E 00   1.0000E 12   0.0          1.4039D 01
 23   24   46   4.6875D-01   0.0          2.5000E-01   8.9375E 00   1.0000E 12   0.0          1.4039D 01
 35   36   47   4.6875D-01   0.0          2.5000E-01   8.9375E 00   1.0000E 12   0.0          1.4039D 01
 47   48   48   4.6875D-01   0.0          2.5000E-01   8.9375E 00   1.0000E 12   0.0          1.4039D 01
  1   37   49   7.8500D-04   7.8500D-04   2.5000E-01   1.2730E-03   1.0000E 12   0.0          1.9996D-03
  2   38   50   3.9300D-01   3.9300D-01   2.5000E-01   6.3500E-01   1.0000E 12   0.0          9.9746D-01
  3   39   51   1.1780D 00   1.1780D 00   2.5000E-01   6.3700E-01   1.0000E 12   0.0          1.0006D 00
  4   40   52   1.9635D 00   1.9635D 00   2.5000E-01   6.3700E-01   1.0000E 12   0.0          1.0006D 00
  5   41   53   2.7489D 00   2.7489D 00   2.5000E-01   6.3700E-01   1.0000E 12   0.0          1.0006D 00
  6   42   54   3.5340D 00   3.5340D 00   2.5000E-01   6.3700E-01   1.0000E 12   0.0          1.0006D 00
  7   43   55   4.2710D 00   4.2710D 00   2.5000E-01   5.5700E-01   1.0000E 12   0.0          8.7493D-01
  8   44   56   4.6630D 00   4.6630D 00   2.5000E-01   7.9600E-02   1.0000E 12   0.0          1.2504D-01
  9   45   57   5.1050D 00   5.1050D 00   2.5000E-01   6.3700E-01   1.0000E 12   0.0          1.0006D 00
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NOD1 NOD2 INDEX  DEL1         DEL2          DLONG        DRAD         HINT          RINT          AREA
  10   46    58  5.8905D 00   5.8905D 00    2.5000E-01   6.3700E-01   1.0000E 12    0.0           1.0006D 00
  11   47    59  6.6510D 00   6.6510D 00    2.5000E-01   5.9700E-01   1.0000E 12    0.0           9.3777D-01
   8   48    60  6.2500D-02   0.0           2.5000E-01   6.0000E 00   1.0000E-24    7.2900E-06    9.4248D 00
  32   24    61  6.2500D-02   0.0           2.5000E-01   6.0000E 00   1.0000E-24    7.2900E-06    9.4248D 00
  20   12    62  6.2500D-02   0.0           2.5000E-01   6.0000E 00   1.0000E-24    7.2900E-06    9.4248D 00
  44   12    63  6.2500D-02   0.0           2.5000E-01   6.0000E 00   1.0000E-24    7.2900E-06    9.4248D 00
  44   36    64  6.2500D-02   0.0           2.5000E-01   6.0000E 00   1.0000E-24    7.2900E-06    9.4248D 00
   1   13    65  7.8500D-04   7.8500D-04    2.5000E-01   1.2730E-03   1.0000E 12    0.0           1.9996D-03
  13   25    66  7.8500D-04   7.8500D-04    2.5000E-01   1.2730E-03   1.0000E 12    0.0           1.9996D-03
  25   37    67  7.8500D-04   7.8500D-04    2.5000E-01   1.2730E-03   1.0000E 12    0.0           1.9996D-03
   2   14    68  3.9300D-01   3.9300D-01    2.5000E-01   6.3500E-01   1.0000E 12    0.0           9.9746D-01
  14   26    69  3.9300D-01   3.9300D-01    2.5000E-01   6.3500E-01   1.0000E 12    0.0           9.9746D-01
  26   38    70  3.9300D-01   3.9300D-01    2.5000E-01   6.3500E-01   1.0000E 12    0.0           9.9746D-01
   3   15    71  1.1780D 00   1.1780D 00    2.5000E-01   6.3700E-01   1.0000E 12    0.0           1.0006D 00
  15   27    72  1.1780D 00   1.1780D 00    2.5000E-01   6.3700E-01   1.0000E 12    0.0           1.0006D 00
  27   39    73  1.1780D 00   1.1780D 00    2.5000E-01   6.3700E-01   1.0000E 12    0.0           1.0006D 00
   4   16    74  1.9635D 00   1.9635D 00    2.5000E-01   6.3700E-01   1.0000E 12    0.0           1.0006D 00
  16   28    75  1.9635D 00   1.9635D 00    2.5000E-01   6.3700E-01   1.0000E 12    0.0           1.0006D 00
  28   40    76  1.9635D 00   1.9635D 00    2.5000E-01   6.3700E-01   1.0000E 12    0.0           1.0006D 00
   5   17    77  2.7489D 00   2.7489D 00    2.5000E-01   6.3700E-01   1.0000E 12    0.0           1.0006D 00
  17   29    78  2.7489D 00   2.7489D 00    2.5000E-01   6.3700E-01   1.0000E 12    0.0           1.0006D 00
  29   41    79  2.7489D 00   2.7489D 00    2.5000E-01   6.3700E-01   1.0000E 12    0.0           1.0006D 00
   6   18    80  3.5340D 00   3.5340D 00    2.5000E-01   6.3700E-01   1.0000E 12    0.0           1.0006D 00
  18   30    81  3.5340D 00   3.5340D 00    2.5000E-01   6.3700E-01   1.0000E 12    0.0           1.0006D 00
  30   42    82  3.5340D 00   3.5340D 00    2.5000E-01   6.3700E-01   1.0000E 12    0.0           1.0006D 00
   7   19    83  4.2710D 00   4.2710D 00    2.5000E-01   5.5700E-01   1.0000E 12    0.0           8.7493D-01
  19   31    84  4.2710D 00   4.2710D 00    2.5000E-01   5.5700E-01   1.0000E 12    0.0           8.7493D-01
  31   43    85  4.2710D 00   4.2710D 00    2.5000E-01   5.5700E-01   1.0000E 12    0.0           8.7493D-01
   8   20    86  4.6630D 00   4.6630D 00    2.5000E-01   7.9600E-02   1.0000E 12    0.0           1.2504D-01
  20   32    87  4.6630D 00   4.6630D 00    2.5000E-01   7.9600E-02   1.0000E 12    0.0           1.2504D-01
  32   44    88  4.6630D 00   4.6630D 00    2.5000E-01   7.9600E-02   1.0000E 12    0.0           1.2504D-01
   9   21    89  5.1050D 00   5.1050D 00    2.5000E-01   6.3700E-01   1.0000E 12    0.0           1.0006D 00
  21   33    90  5.1050D 00   5.1050D 00    2.5000E-01   6.3700E-01   1.0000E 12    0.0           1.0006D 00
  33   45    91  5.1050D 00   5.1050D 00    2.5000E-01   6.3700E-01   1.0000E 12    0.0           1.0006D 00
  10   22    92  5.8905D 00   5.8905D 00    2.5000E-01   6.3700E-01   1.0000E 12    0.0           1.0006D 00
  22   34    93  5.8905D 00   5.8905D 00    2.5000E-01   6.3700E-01   1.0000E 12    0.0           1.0006D 00
  34   46    94  5.8905D 00   5.8905D 00    2.5000E-01   6.3700E-01   1.0000E 12    0.0           1.0006D 00
  11   23    95  6.6510D 00   6.6510D 00    2.5000E-01   5.9700E-01   1.0000E 12    0.0           9.3777D-01
  23   35    96  6.6510D 00   6.6510D 00    2.5000E-01   5.9700E-01   1.0000E 12    0.0           9.3777D-01
  35   47    97  6.6510D 00   6.6510D 00    2.5000E-01   5.9700E-01   1.0000E 12    0.0           9.3777D-01
   8   24    98  6.2500D-02   0.0           2.5000E-01   6.0000E 00   1.0000E-24    7.2900E-06    9.4248D 00
  20   36    99  6.2500D-02   0.0           2.5000E-01   6.0000E 00   1.0000E-24    7.2900E-06    9.4248D 00
  32   48   100  6.2500D-02   0.0           2.5000E-01   6.0000E 00   1.0000E-24    7.2900E-06    9.4248D 00
=========================================================================================================
DATA BLOCK  60                 EXTERNAL THERMAL CONNECTIONS

 NODS NODSB INDEX LTABH     POWER         DLONG        DRAD         HSURE         RSURE         AREAS
   12  2001     1     0     0.0           2.5000E-01   8.9375E 00   1.0000D 06    0.0           1.4039D 01
   24  2002     2     0     0.0           2.5000E-01   8.9375E 00   1.0000D 06    0.0           1.4039D 01
   36  2003     3     0     0.0           2.5000E-01   8.9375E 00   1.0000D 06    0.0           1.4039D 01
   48  2004     4     0     0.0           2.5000E-01   8.9375E 00   1.0000D 06    0.0           1.4039D 01
---------------------------------------------------------------------------------------------------------
```

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------------------------------------------------------------------------------------------------------------------------
DATA BLOCK   70                    BOUNDARY TEMPERATURE VARIATION.

  NODB  INDEX  LTABT      TEMPB              SLOPE             TIMEB
  2001      1     12     8.400000E 01                        1.200000E 02
                         7.900000E 01   -4.166666E-02        2.400000E 02
                         7.200000E 01   -5.833333E-02        3.600000E 02
                         7.100000E 01   -8.333333E-03        4.800000E 02
                         6.400000E 01   -5.833333E-02        6.000000E 02
                         8.400000E 01    1.666666E-01        7.200000E 02
                         1.210000E 02    3.083333E-01        8.400000E 02
                         1.460000E 02    2.083333E-01        9.600000E 02
                         1.540000E 02    6.666666E-02        1.080000E 03
                         1.510000E 02   -2.500000E-02        1.200000E 03
                         1.310000E 02   -1.666666E-01        1.320000E 03
                         9.900000E 01   -2.666667E-01        1.440000E 03

  NODB  INDEX  LTABT      TEMPB              SLOPE             TIMEB
  2002      2     12     8.700000E 01                        1.200000E 02
                         8.200000E 01   -4.166666E-02        2.400000E 02
                         7.700000E 01   -4.166666E-02        3.600000E 02
                         7.300000E 01   -3.333333E-02        4.800000E 02
                         6.700000E 01   -5.000000E-02        6.000000E 02
                         7.700000E 01    8.333331E-02        7.200000E 02
                         9.600000E 01    1.583333E-01        8.400000E 02
                         1.130000E 02    1.416667E-01        9.600000E 02
                         1.330000E 02    1.666666E-01        1.080000E 03
                         1.520000E 02    1.583333E-01        1.200000E 03
                         1.470000E 02   -4.166666E-02        1.320000E 03
                         1.030000E 02   -3.666666E-01        1.440000E 03

  NODB  INDEX  LTABT      TEMPB              SLOPE             TIMEB
  2003      3     12     9.100000E 01                        1.200000E 02
                         8.700000E 01   -3.333333E-02        2.400000E 02
                         8.300000E 01   -3.333333E-02        3.600000E 02
                         7.900000E 01   -3.333333E-02        4.800000E 02
                         7.300000E 01   -5.000000E-02        6.000000E 02
                         8.400000E 01    9.166664E-02        7.200000E 02
                         9.800000E 01    1.166666E-01        8.400000E 02
                         1.060000E 02    6.666666E-02        9.600000E 02
                         1.110000E 02    4.166666E-02        1.080000E 03
                         1.180000E 02    5.833333E-02        1.200000E 03
                         1.210000E 02    2.500000E-02        1.320000E 03
                         1.030000E 02   -1.500000E-01        1.440000E 03

  NODB  INDEX  LTABT      TEMPB              SLOPE             TIMEB
  2004      4     12     9.600000E 01                        1.200000E 02
                         9.000000E 01   -5.000000E-02        2.400000E 02
                         8.500000E 01   -4.166666E-02        3.600000E 02
                         8.100000E 01   -3.333333E-02        4.800000E 02
                         7.500000E 01   -5.000000E-02        6.000000E 02
                         8.400000E 01    7.499999E-02        7.200000E 02
                         1.000000E 02    1.333333E-01        8.400000E 02
                         1.110000E 02    9.166664E-02        9.600000E 02
                         1.220000E 02    9.166664E-02        1.080000E 03
                         1.310000E 02    7.499999E-02        1.200000E 03
                         1.300000E 02   -8.333333E-03        1.320000E 03
                         1.090000E 02   -1.750000E-01        1.440000E 03
========================================================================================================================
DATA ENDED -10                      LAST CARD OF DATA DECK
========================================================================================================================
========================================================================================================================
```

```
TRUMP OUTPUT DATA                                                                                    DATA DECK    1
  *   MISSLE PROBLEM    TWO DIMENSIONAL
===========================================================================================================================
   PRINTOUT      CYCLE    TOO FAST  TOO SLOW     KWIT      DELTMX           SMALL           TVARY       NUTS
       1           0          0         1          0     3.13978E-05     3.13977E-05     1.00000E 00     0

     TOTAL TIME      TIME STEP       HEAT FLOW     TEMP FROM FLUX   FLUX RATE      TEMP RATE
   1.00000E-12     1.00000E-12     4.29983E-14      3.16773E-14   4.29984E-02    3.16773E-02

     AVG TEMP      HEAT CAPACITY    HEAT CONTENT      GEN RATE       HEAT GEN       TEMP FROM GEN
   1.14000E 02      1.357390 00     1.54742E 02     0.0             0.0            0.0
===========================================================================================================================

NODE       TEMP          DT              DDT            GE N RATE      W             H             F           CURE AT 280 F
   1     0.1140D 03   0.0             0.0             0.0            0.3702E-05   0.0           0.0            0.0
  13     0.1140D 03   0.0             0.0             0.0            0.3702E-05   0.0           0.0            0.0
  25     0.1140D 03   0.0             0.0             0.0            0.3702E-05   0.0           0.0            0.0
  37     0.1140D 03   0.0             0.0             0.0            0.3702E-05   0.0           0.0            0.0
   2     0.1140D 03   0.0             0.0             0.0            0.9254E 00   0.0           0.0            0.0
  14     0.1140D 03   0.0             0.0             0.0            0.9254E 00   0.0           0.0            0.0
  26     0.1140D 03   0.0             0.0             0.0            0.9254E 00   0.0           0.0            0.0
  38     0.1140D 03   0.0             0.0             0.0            0.9254E 00   0.0           0.0            0.0
   3     0.1140D 03   0.0             0.0             0.0            0.2776E 01   0.0           0.0            0.0
  15     0.1140D 03   0.0             0.0             0.0            0.2776E 01   0.0           0.0            0.0
  27     0.1140D 03   0.0             0.0             0.0            0.2776E 01   0.0           0.0            0.0
  39     0.1140D 03   0.0             0.0             0.0            0.2776E 01   0.0           0.0            0.0
   4     0.1140D 03   0.0             0.0             0.0            0.4627E 01   0.0           0.0            0.0
  16     0.1140D 03   0.0             0.0             0.0            0.4627E 01   0.0           0.0            0.0
  28     0.1140D 03   0.0             0.0             0.0            0.4627E 01   0.0           0.0            0.0
  40     0.1140D 03   0.0             0.0             0.0            0.4627E 01   0.0           0.0            0.0
   5     0.1140D 03   0.0             0.0             0.0            0.6478E 01   0.0           0.0            0.0
  17     0.1140D 03   0.0             0.0             0.0            0.6478E 01   0.0           0.0            0.0
  29     0.1140D 03   0.0             0.0             0.0            0.6478E 01   0.0           0.0            0.0
  41     0.1140D 03   0.0             0.0             0.0            0.6478E 01   0.0           0.0            0.0
   6     0.1140D 03   0.0             0.0             0.0            0.8329E 01   0.0           0.0            0.0
  18     0.1140D 03   0.0             0.0             0.0            0.8329E 01   0.0           0.0            0.0
  30     0.1140D 03   0.0             0.0             0.0            0.8329E 01   0.0           0.0            0.0
  42     0.1140D 03   0.0             0.0             0.0            0.8329E 01   0.0           0.0            0.0
   7     0.1140D 03   0.0             0.0             0.0            0.7461E 01   0.0           0.0            0.0
  19     0.1140D 03   0.0             0.0             0.0            0.7461E 01   0.0           0.0            0.0
  31     0.1140D 03   0.0             0.0             0.0            0.7461E 01   0.0           0.0            0.0
  43     0.1140D 03   0.0             0.0             0.0            0.7461E 01   0.0           0.0            0.0
   8     0.1140D 03  -0.4135D-12     -0.4135D 00      0.0            0.8047E 01  -0.2919E-13   -0.2919E-13     0.0
  20     0.1140D 03  -0.3818D-12     -0.3818D 00      0.0            0.8047E 01  -0.2695E-13   -0.2695E-13     0.0
  32     0.1140D 03  -0.3247D-12     -0.3247D 00      0.0            0.8047E 01  -0.2292E-13   -0.2292E-13     0.0
  44     0.1140D 03  -0.2337D-12     -0.2337D 00      0.0            0.8047E 01  -0.1650E-13   -0.1650E-13     0.0
   9     0.1140D 03   0.0             0.0             0.0            0.1218E-01   0.0           0.0            0.0
  21     0.1140D 03   0.0             0.0             0.0            0.1218E-01   0.0           0.0            0.0
  33     0.1140D 03   0.0             0.0             0.0            0.1218E-01   0.0           0.0            0.0
  45     0.1140D 03   0.0             0.0             0.0            0.1218E-01   0.0           0.0            0.0
  10     0.1140D 03   0.0             0.0             0.0            0.1405E-01   0.0           0.0            0.0
  22     0.1140D 03   0.0             0.0             0.0            0.1405E-01   0.0           0.0            0.0
  34     0.1140D 03   0.0             0.0             0.0            0.1405E-01   0.0           0.0            0.0
  46     0.1140D 03   0.0             0.0             0.0            0.1405E-01   0.0           0.0            0.0
  11     0.1140D 03  -0.1291D-09     -0.1291D 03      0.0            0.1488E-01  -0.1685E-13   -0.1685E-13     0.0
  23     0.1140D 03  -0.1136D-09     -0.1136D 03      0.0            0.1488E-01  -0.1483E-13   -0.1483E-13     0.0
  35     0.1140D 03  -0.9811D-10     -0.9811D 02      0.0            0.1488E-01  -0.1280E-13   -0.1280E-13     0.0
  47     0.1140D 03  -0.6197D-10     -0.6197D 02      0.0            0.1488E-01  -0.8086E-14   -0.8086E-14     0.0

NODE       TEMP          DT              DDT            GE N RATE      W             H             F           CURE AT 280 F
  12     0.8900D 02  -0.2500D 02      0.0             0.0            0.2723E-23  -0.7649E-24    0.6126E-13     0.0
  24     0.9200D 02  -0.2200D 02      0.0             0.0            0.2815E-23  -0.6731E-24    0.5391E-13     0.0
  36     0.9500D 02  -0.1900D 02      0.0             0.0            0.2907E-23  -0.5813E-24    0.4655E-13     0.0
  48     0.1020D 03  -0.1200D 02      0.0             0.0            0.3121E-23  -0.3672E-24    0.2940E-13     0.0
===========================================================================================================================
   MATERIAL DATA

     NAME   MATL      TOT CAP          TOT HEAT         AVG TEMP        TMELT            HMELT
     SAND     1     1.07359E 00      1.22389E 02      1.14000E 02     0.0              0.0
     STEL     2     2.82356E-01      3.21885E 01      1.14000E 02     0.0              0.0
     AIR      3     1.44246E-03      1.64440E-01      1.14000E 02     0.0              0.0
   ===================================================================================================================
```

```
TRUMP OUTPUT DATA                                                                        DATA DECK    1
 *   MISSLE PROBLEM    TWO DIMENSIONAL
=====================================================================================================
  PRINTOUT    CYCLE   TOO FAST  TOO SLOW     KWIT     DELTMX           SMALL          TVARY       NUTS
     2          1        1         0           0   8.97912E-02    8.97912E-02    1.00000E 00      0

   TOTAL TIME     TIME STEP      HEAT FLOW     TEMP FROM FLUX   FLUX RATE      TEMP RATE
  3.13978E-05    3.13978E-05   -4.49227E-06   -3.30950E-06   -1.43076E-01   -1.05406E-01

   AVG TEMP      HEAT CAPACITY   HEAT CONTENT     GEN RATE        HEAT GEN       TEMP FROM GEN
  1.14000E 02    1.35739D 00     1.54742E 02     0.0             0.0            0.0
=====================================================================================================
NODE      TEMP        DT            DDT             GE N RATE        W            H             F             CURE AT 280 F
   1      0.1140D 03  0.0           0.0             0.0              0.3702E-05   0.0           0.0           0.0
  13      0.1140D 03  0.0           0.0             0.0              0.3702E-05   0.0           0.0           0.0
  25      0.1140D 03  0.0           0.0             0.0              0.3702E-05   0.0           0.0           0.0
  37      0.1140D 03  0.0           0.0             0.0              0.3702E-05   0.0           0.0           0.0
   2      0.1140D 03  0.0           0.0             0.0              0.9254E 00   0.0           0.0           0.0
  14      0.1140D 03  0.0           0.0             0.0              0.9254E 00   0.0           0.0           0.0
  26      0.1140D 03  0.0           0.0             0.0              0.9254E 00   0.0           0.0           0.0
  38      0.1140D 03  0.0           0.0             0.0              0.9254E 00   0.0           0.0           0.0
   3      0.1140D 03  0.0           0.0             0.0              0.2776E 01   0.0           0.0           0.0
  15      0.1140D 03  0.0           0.0             0.0              0.2776E 01   0.0           0.0           0.0
  27      0.1140D 03  0.0           0.0             0.0              0.2776E 01   0.0           0.0           0.0
  39      0.1140D 03  0.0           0.0             0.0              0.2776E 01   0.0           0.0           0.0
   4      0.1140D 03  0.0           0.0             0.0              0.4627E 01   0.0           0.0           0.0
  16      0.1140D 03  0.0           0.0             0.0              0.4627E 01   0.0           0.0           0.0
  28      0.1140D 03  0.0           0.0             0.0              0.4627E 01   0.0           0.0           0.0
  40      0.1140D 03  0.0           0.0             0.0              0.4627E 01   0.0           0.0           0.0
   5      0.1140D 03  0.0           0.0             0.0              0.6478E 01   0.0           0.0           0.0
  17      0.1140D 03  0.0           0.0             0.0              0.6478E 01   0.0           0.0           0.0
  29      0.1140D 03  0.0           0.0             0.0              0.6478E 01   0.0           0.0           0.0
  41      0.1140D 03  0.0           0.0             0.0              0.6478E 01   0.0           0.0           0.0
   6      0.1140D 03  0.0           0.0             0.0              0.8329E 01   0.0           0.0           0.0
  18      0.1140D 03  0.0           0.0             0.0              0.8329E 01   0.0           0.0           0.0
  30      0.1140D 03  0.0           0.0             0.0              0.8329E 01   0.0           0.0           0.0
  42      0.1140D 03  0.0           0.0             0.0              0.8329E 01   0.0           0.0           0.0
   7      0.1140D 03  -0.1294D-17   -0.4120D-13     0.0              0.7461E 01   -0.8466E-19   -0.8466E-19   0.0
  19      0.1140D 03  -0.1194D-17   -0.3803D-13     0.0              0.7461E 01   -0.7815E-19   -0.7815E-19   0.0
  31      0.1140D 03  -0.1017D-17   -0.3240D-13     0.0              0.7461E 01   -0.6657E-19   -0.6657E-19   0.0
  43      0.1140D 03  -0.7297D-18   -0.2324D-13     0.0              0.7461E 01   -0.4776E-19   -0.4776E-19   0.0
   8      0.1140D 03  -0.1218D-04   -0.3880D 00     0.0              0.8047E 01   -0.8599E-06   -0.8599E-06   0.0
  20      0.1140D 03  -0.1132D-04   -0.3604D 00     0.0              0.8047E 01   -0.7987E-06   -0.7987E-06   0.0
  32      0.1140D 03  -0.9701D-05   -0.3090D 00     0.0              0.8047E 01   -0.6848E-06   -0.6848E-06   0.0
  44      0.1140D 03  -0.7066D-05   -0.2251D 00     0.0              0.8047E 01   -0.4988E-06   -0.4988E-06   0.0
   9      0.1140D 03  -0.5180D-16   -0.1650D-11     0.0              0.1218E-01   -0.5534E-20   -0.5534E-20   0.0
  21      0.1140D 03  -0.4782D-16   -0.1523D-11     0.0              0.1218E-01   -0.5109E-20   -0.5109E-20   0.0
  33      0.1140D 03  -0.4073D-16   -0.1297D-11     0.0              0.1218E-01   -0.4352E-20   -0.4352E-20   0.0
  45      0.1140D 03  -0.2922D-16   -0.9307D-12     0.0              0.1218E-01   -0.3122E-20   -0.3122E-20   0.0
  10      0.1140D 03  -0.9596D-14   -0.3056D-09     0.0              0.1405E-01   -0.1183E-17   -0.1183E-17   0.0
  22      0.1140D 03  -0.8445D-14   -0.2690D-09     0.0              0.1405E-01   -0.1041E-17   -0.1041E-17   0.0
  34      0.1140D 03  -0.7294D-14   -0.2323D-09     0.0              0.1405E-01   -0.8991E-18   -0.8991E-18   0.0
  46      0.1140D 03  -0.4606D-14   -0.1467D-09     0.0              0.1405E-01   -0.5679E-18   -0.5679E-18   0.0
  11      0.1140D 03  -0.4053D-02   -0.1291D 03     0.0              0.1488E-01   -0.5289E-06   -0.5289E-06   0.0
  23      0.1140D 03  -0.3566D-02   -0.1136D 03     0.0              0.1488E-01   -0.4654E-06   -0.4654E-06   0.0
  35      0.1140D 03  -0.3080D-02   -0.9810D 02     0.0              0.1488E-01   -0.4019E-06   -0.4019E-06   0.0
  47      0.1140D 03  -0.1945D-02   -0.6196D 02     0.0              0.1488E-01   -0.2539E-06   -0.2539E-06   0.0

NODE      TEMP        DT            DDT             GE N RATE        W            H             F             CURE AT 280 F
  12      0.8900D 02  0.4225D-08    0.0             0.0              0.2723E-23   -0.7649E-24   0.6063E-13    0.0
  24      0.9200D 02  0.3732D-08    0.0             0.0              0.2815E-23   -0.6731E-24   0.5335E-13    0.0
  36      0.9500D 02  0.3235D-08    0.0             0.0              0.2907E-23   -0.5813E-24   0.4607E-13    0.0
  48      0.1020D 03  0.2062D-08    0.0             0.0              0.3121E-23   -0.3672E-24   0.2909E-13    0.0
=====================================================================================================
  MATERIAL DATA

    NAME  MATL    TOT CAP        TOT HEAT       AVG TEMP      TMELT         HMELT
    SAND    1    1.07359E 00    1.22389E 02    1.14000E 02   0.0           0.0
    STEL    2    2.82356E-01    3.21885E 01    1.14000E 02   0.0           0.0
    AIR     3    1.44246E-03    1.64438E-01    1.13999E 02   0.0           0.0
  -----------------------------------------------------------------------------------
```

```
TRUMP OUTPUT DATA                                                                                     DATA DECK    1
 *   MISSLE PROBLEM    TWO DIMENSIONAL
=====================================================================================================================
  PRINTOUT     CYCLE    TOO FAST  TOO SLOW      KWIT      DELTMX           SMALL           TVARY        NUTS
     3           20         11        0           0    1.08086E 01     1.00000E 00     1.00000E 00     12

   TOTAL TIME      TIME STEP       HEAT FLOW     TEMP FROM FLUX   FLUX RATE        TEMP RATE
  2.48340E 01     4.86662E 00     2.52999E 03     1.86387E 03    1.01876E 02      7.50532E 01

    AVG TEMP      HEAT CAPACITY    HEAT CONTENT     GEN RATE        HEAT GEN        TEMP FROM GEN
  1.12416E 02      1.35739D 00     1.52592E 02     0.0              0.0              0.0
=====================================================================================================================

NODE        TEMP          DT            DDT        GE N RATE        W            H             F          CURE AT 280 F
   1     0.1140D 03  -0.1008D-05  -0.2072D-06   0.0          0.3702E-05  -0.3765E-13  -0.1733E-09   0.0
  13     0.1140D 03  -0.1009D-05  -0.2073D-06   0.0          0.3702E-05  -0.3766E-13  -0.1734E-09   0.0
  25     0.1140D 03  -0.9940D-06  -0.2043D-06   0.0          0.3702E-05  -0.3710E-13  -0.1733E-09   0.0
  37     0.1140D 03  -0.9843D-06  -0.2023D-06   0.0          0.3702E-05  -0.3673E-13  -0.1734E-09   0.0
   2     0.1140D 03  -0.3044D-04  -0.6254D-05   0.0          0.9254E 00  -0.2887E-06  -0.2887E-06   0.0
  14     0.1140D 03  -0.2872D-04  -0.5901D-05   0.0          0.9254E 00  -0.2722E-06  -0.2722E-06   0.0
  26     0.1140D 03  -0.2461D-04  -0.5058D-05   0.0          0.9254E 00  -0.2333E-06  -0.2333E-06   0.0
  38     0.1140D 03  -0.1879D-04  -0.3861D-05   0.0          0.9254E 00  -0.1777E-06  -0.1777E-06   0.0
   3     0.1140D 03  -0.4594D-03  -0.9440D-04   0.0          0.2776E 01  -0.1427E-04  -0.1427E-04   0.0
  15     0.1140D 03  -0.4291D-03  -0.8818D-04   0.0          0.2776E 01  -0.1333E-04  -0.1333E-04   0.0
  27     0.1140D 03  -0.3678D-03  -0.7557D-04   0.0          0.2776E 01  -0.1142E-04  -0.1142E-04   0.0
  39     0.1140D 03  -0.2731D-03  -0.5612D-04   0.0          0.2776E 01  -0.8466E-05  -0.8466E-05   0.0
   4     0.1140D 03  -0.6201D-02  -0.1274D-02   0.0          0.4627E 01  -0.3696E-03  -0.3696E-03   0.0
  16     0.1140D 03  -0.5795D-02  -0.1191D-02   0.0          0.4627E 01  -0.3451F-03  -0.3451E-03   0.0
  28     0.1140D 03  -0.4966D-02  -0.1020D-02   0.0          0.4627E 01  -0.2958E-03  -0.2958E-03   0.0
  40     0.1140D 03  -0.3700D-02  -0.7604D-03   0.0          0.4627E 01  -0.2196E-03  -0.2196E-03   0.0
   5     0.1139D 03  -0.5443D-01  -0.1119D-01   0.0          0.6472E 01  -0.5678E-02  -0.5678E-02   0.0
  17     0.1139D 03  -0.5101D-01  -0.1048D-01   0.0          0.6473E 01  -0.5310E-02  -0.5310E-02   0.0
  29     0.1139D 03  -0.4372D-01  -0.8984D-02   0.0          0.6474E 01  -0.4551E-02  -0.4551E-02   0.0
  41     0.1139D 03  -0.3294D-01  -0.6769D-02   0.0          0.6475F 01  -0.3404E-02  -0.3404E-02   0.0
   6     0.1133D 03  -0.2766D 00  -0.5683D-01   0.0          0.8276E 01  -0.5328E-01  -0.5328E-01   0.0
  18     0.1133D 03  -0.2607D 00  -0.5356D-01   0.0          0.8279E 01  -0.4998E-01  -0.4998E-01   0.0
  30     0.1134D 03  -0.2235D 00  -0.4592D-01   0.0          0.8286E 01  -0.4284E-01  -0.4284E-01   0.0
  42     0.1136D 03  -0.1721D 00  -0.3536D-01   0.0          0.8297E 01  -0.3243E-01  -0.3243E-01   0.0
   7     0.1109D 03  -0.6409D 00  -0.1317D 00   0.0          0.7259E 01  -0.2026E 00  -0.2026E 00   0.0
  19     0.1111D 03  -0.6112D 00  -0.1256D 00   0.0          0.7270E 01  -0.1909E 00  -0.1909E 00   0.0
  31     0.1115D 03  -0.5248D 00  -0.1078D 00   0.0          0.7298E 01  -0.1637E 00  -0.1637E 00   0.0
  43     0.1121D 03  -0.4231D 00  -0.8694D-01   0.0          0.7335E 01  -0.1262E 00  -0.1262E 00   0.0
   8     0.1088D 03  -0.6770D 00  -0.1391D 00   0.0          0.7679E 01  -0.3679E 00  -0.3679E 00   0.0
  20     0.1091D 03  -0.6519D 00  -0.1340D 00   0.0          0.7699E 01  -0.3479E 00  -0.3479E 00   0.0
  32     0.1098D 03  -0.5614D 00  -0.1153D 00   0.0          0.7749E 01  -0.2985E 00  -0.2985E 00   0.0
  44     0.1107D 03  -0.4719D 00  -0.9697D-01   0.0          0.7814E 01  -0.2335E 00  -0.2335E 00   0.0
   9     0.1045D 03  -0.5760D 00  -0.1184D 00   0.0          0.1117E-01  -0.1013E-02  -0.1013E-02   0.0
  21     0.1053D 03  -0.5566D 00  -0.1144D 00   0.0          0.1125E-01  -0.9269E-03  -0.9266E-03   0.0
  33     0.1065D 03  -0.4773D 00  -0.9807D-01   0.0          0.1138F-01  -0.7961E-03  -0.7959E-03   0.0
  45     0.1086D 03  -0.4245D 00  -0.8723D-01   0.0          0.1160E-01  -0.5783E-03  -0.5782E-03   0.0
  10     0.9713D 02  -0.4092D 00  -0.8408D-01   0.0          0.1197E-01  -0.2080E-02  -0.2080E-02   0.0
  22     0.9887D 02  -0.3985D 00  -0.8188D-01   0.0          0.1219E-01  -0.1865E-02  -0.1865E-02   0.0
  34     0.1010D 03  -0.3370D 00  -0.6925D-01   0.0          0.1245E-01  -0.1603E-02  -0.1603E-02   0.0
  46     0.1050D 03  -0.3439D 00  -0.7067D-01   0.0          0.1294E-01  -0.1109E-02  -0.1108E-02   0.0
  11     0.9076D 02  -0.2657D 00  -0.5459D-01   0.0          0.1184E-01  -0.3032E-02  -0.3032E-02   0.0
  23     0.9336D 02  -0.2623D 00  -0.5390D-01   0.0          0.1218E-01  -0.2693E-02  -0.2693E-02   0.0
  35     0.9624D 02  -0.2156D 00  -0.4430D-01   0.0          0.1256E-01  -0.2317E-02  -0.2317E-02   0.0
  47     0.1020D 03  -0.2739D 00  -0.5628D-01   0.0          0.1331E-01  -0.1563E-02  -0.1563E-02   0.0

NODE        TEMP          DT            DDT        GE N RATE        W            H             F          CURE AT 280 F
  12     0.8797D 02  -0.2028D 00  -0.4167D-01   0.0          0.2691E-23  -0.7966E-24   0.6336E 03   0.0
  24     0.9097D 02  -0.2028D 00  -0.4167D-01   0.0          0.2783E-23  -0.7048E-24   0.6336E 03   0.0
  36     0.9417D 02  -0.1622D 00  -0.3333D-01   0.0          0.2881E-23  -0.6067E-24   0.5072E 03   0.0
  48     0.1008D 03  -0.2433D 00  -0.5000D-01   0.0          0.3083E-23  -0.4051E-24   0.7577E 03   0.0
=====================================================================================================================
   MATERIAL DATA

     NAME  MATL     TOT CAP        TOT HEAT        AVG TEMP       TMELT          HMELT
     SAND    1    1.07359E 00    1.21507E 02    1.13178E 02    0.0            0.0
     STEL    2    2.82356E-01    3.09406E 01    1.09580E 02    0.0            0.0
     AIR     3    1.44246E-03    1.44862E-01    1.00428E 02    0.0            0.0
   ----------------------------------------------------------------------------------
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TRUMP OUTPUT DATA                                                                      DATA DECK    1

  *   MISSLE PROBLEM     TWO DIMENSIONAL
=====================================================================================================

   PRINTOUT     CYCLE    TOO FAST   TOO SLOW     KWIT       DELTMX           SMALL           TVARY       NUTS
      4           40        11          0          0     1.00000E 12     1.00000E 00     1.00000E 00     6

    TOTAL TIME      TIME STEP        HEAT FLOW      TEMP FROM FLUX    FLUX RATE       TEMP RATE
   3.07043E 02     1.66156E 01      3.59496E 03       2.64844E 03     1.17083E 01     8.62564E 00

     AVG TEMP      HEAT CAPACITY     HEAT CONTENT     GEN RATE         HEAT GEN       TEMP FROM GEN
   9.94270E 01      1.35739D 00      1.34961E 02     0.0              0.0             0.0
=====================================================================================================

NODE        TEMP           DT              DDT          GE N RATE          W           H              F          CURE AT 280 F
   1    0.1101D 03   -0.6264D 00   -0.3770D-01     0.0           0.3577E-05  -0.1251E-06  -0.6692E-03    0.0
  13    0.1101D 03   -0.6263D 00   -0.3770D-01     0.0           0.3577E-05  -0.1251E-06  -0.6692E-03    0.0
  25    0.1101D 03   -0.6263D 00   -0.3769D-01     0.0           0.3577E-05  -0.1251E-06  -0.6692E-03    0.0
  37    0.1101D 03   -0.6263D 00   -0.3769D-01     0.0           0.3577E-05  -0.1251E-06  -0.6692E-03    0.0
   2    0.1071D 03   -0.6678D 00   -0.4019D-01     0.0           0.8692E 00  -0.5625E-01  -0.5626E-01    0.0
  14    0.1071D 03   -0.6661D 00   -0.4009D-01     0.0           0.8692E 00  -0.5625E-01  -0.5626E-01    0.0
  26    0.1073D 03   -0.6553D 00   -0.3944D-01     0.0           0.8711E 00  -0.5438E-01  -0.5439E-01    0.0
  38    0.1074D 03   -0.6572D 00   -0.3955D-01     0.0           0.8716E 00  -0.5387E-01  -0.5388E-01    0.0
   3    0.1060D 03   -0.6880D 00   -0.4140D-01     0.0           0.2583E 01  -0.1936E 00  -0.1936E 00    0.0
  15    0.1061D 03   -0.6831D 00   -0.4111D-01     0.0           0.2584E 01  -0.1923E 00  -0.1923E 00    0.0
  27    0.1067D 03   -0.6558D 00   -0.3947D-01     0.0           0.2598E 01  -0.1786E 00  -0.1786E 00    0.0
  39    0.1069D 03   -0.6615D 00   -0.3981D-01     0.0           0.2603E 01  -0.1735E 00  -0.1735E 00    0.0
   4    0.1042D 03   -0.7121D 00   -0.4286D-01     0.0           0.4230E 01  -0.3967E 00  -0.3967E 00    0.0
  16    0.1044D 03   -0.7028D 00   -0.4230D-01     0.0           0.4236E 01  -0.3911E 00  -0.3911E 00    0.0
  28    0.1053D 03   -0.6631D 00   -0.3991D-01     0.0           0.4272E 01  -0.3548E 00  -0.3548E 00    0.0
  40    0.1056D 03   -0.6756D 00   -0.4066D-01     0.0           0.4287E 01  -0.3399E 00  -0.3399E 00    0.0
   5    0.1016D 03   -0.7348D 00   -0.4422D-01     0.0           0.5771E 01  -0.7071E 00  -0.7070E 00    0.0
  17    0.1018D 03   -0.7178D 00   -0.4320D-01     0.0           0.5786E 01  -0.6923E 00  -0.6923E 00    0.0
  29    0.1031D 03   -0.6700D 00   -0.4032D-01     0.0           0.5857E 01  -0.6209E 00  -0.6209E 00    0.0
  41    0.1036D 03   -0.6932D 00   -0.4172D-01     0.0           0.5886E 01  -0.5919E 00  -0.5919E 00    0.0
   6    0.9801D 02   -0.7531D 00   -0.4533D-01     0.0           0.7161E 01  -0.1168E 01  -0.1168E 01    0.0
  18    0.9843D 02   -0.7221D 00   -0.4346D-01     0.0           0.7192E 01  -0.1137E 01  -0.1137E 01    0.0
  30    0.1001D 03   -0.6695D 00   -0.4029D-01     0.0           0.7314E 01  -0.1015E 01  -0.1015E 01    0.0
  42    0.1007D 03   -0.7065D 00   -0.4252D-01     0.0           0.7359E 01  -0.9695E 00  -0.9695E 00    0.0
   7    0.9411D 02   -0.7668D 00   -0.4615D-01     0.0           0.6159E 01  -0.1302E 01  -0.1302E 01    0.0
  19    0.9474D 02   -0.7145D 00   -0.4300D-01     0.0           0.6201E 01  -0.1261E 01  -0.1261E 01    0.0
  31    0.9684D 02   -0.6587D 00   -0.3964D-01     0.0           0.6338E 01  -0.1123E 01  -0.1123E 01    0.0
  43    0.9751D 02   -0.7082D 00   -0.4263D-01     0.0           0.6382E 01  -0.1080E 01  -0.1079E 01    0.0
   8    0.9217D 02   -0.7717D 00   -0.4644D-01     0.0           0.6506E 01  -0.1541E 01  -0.1541E 01    0.0
  20    0.9292D 02   -0.7077D 00   -0.4259D-01     0.0           0.6559E 01  -0.1488E 01  -0.1488E 01    0.0
  32    0.9522D 02   -0.6503D 00   -0.3914D-01     0.0           0.6722E 01  -0.1326E 01  -0.1325E 01    0.0
  44    0.9589D 02   -0.7050D 00   -0.4243D-01     0.0           0.6769E 01  -0.1278E 01  -0.1278E 01    0.0
   9    0.8868D 02   -0.8156D 00   -0.4909D-01     0.0           0.9475E-02  -0.2705E-02  -0.2690E-02    0.0
  21    0.9009D 02   -0.7077D 00   -0.4259D-01     0.0           0.9625E-02  -0.2555E-02  -0.2522E-02    0.0
  33    0.9304D 02   -0.6339D 00   -0.3815D-01     0.0           0.9940E-02  -0.2239E-02  -0.2211E-02    0.0
  45    0.9404D 02   -0.7046D 00   -0.4241D-01     0.0           0.1005E-01  -0.2132E-02  -0.2104E-02    0.0
  10    0.8262D 02   -0.8879D 00   -0.5343D-01     0.0           0.1019E-01  -0.3868E-02  -0.3853E-02    0.0
  22    0.8520D 02   -0.7037D 00   -0.4235D-01     0.0           0.1050E-01  -0.3551E-02  -0.3515E-02    0.0
  34    0.8930D 02   -0.6012D 00   -0.3618D-01     0.0           0.1101E-01  -0.3045E-02  -0.3014E-02    0.0
  46    0.9091D 02   -0.7008D 00   -0.4218D-01     0.0           0.1121E-01  -0.2846E-02  -0.2815E-02    0.0
  11    0.7740D 02   -0.9461D 00   -0.5694D-01     0.0           0.1010E-01  -0.4777E-02  -0.4764E-02    0.0
  23    0.8102D 02   -0.6968D 00   -0.4194D-01     0.0           0.1057E-01  -0.4303E-02  -0.4272E-02    0.0
  35    0.8614D 02   -0.5693D 00   -0.3426D-01     0.0           0.1124E-01  -0.3636E-02  -0.3609E-02    0.0
  47    0.8831D 02   -0.6952D 00   -0.4184D-01     0.0           0.1152E-01  -0.3352E-02  -0.3325E-02    0.0

NODE        TEMP           DT              DDT          GE N RATE          W           H              F          CURE AT 280 F
  12    0.7509D 02   -0.9692D 00   -0.5833D-01     0.0           0.2297E-23  -0.1191E-23   0.9254E 03    0.0
  24    0.7921D 02   -0.6923D 00   -0.4167D-01     0.0           0.2423E-23  -0.1065E-23   0.9011E 03    0.0
  36    0.8477D 02   -0.5538D 00   -0.3333D-01     0.0           0.2593E-23  -0.8945E-24   0.7213E 03    0.0
  48    0.8721D 02   -0.6923D 00   -0.4167D-01     0.0           0.2668E-23  -0.8198E-24   0.1067E 04    0.0
=====================================================================================================
   MATERIAL DATA

     NAME   MATL      TOT CAP         TOT HEAT         AVG TEMP         TMELT            HMELT
     SAND     1     1.07359E 00     1.08280E 02     1.00858E 02     0.0               0.0
     STEL     2     2.82356E-01     2.65557E 01     9.40505E 01     0.0               0.0
     AIR      3     1.44246E-03     1.25430E-01     8.69560E 01     0.0               0.0
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TRUMP OUTPUT DATA                                                                          DATA DECK    1
  *   MISSLE PROBLEM    TWO DIMENSIONAL
==========================================================================================================
   PRINTOUT     CYCLE    TOO FAST  TOO SLOW      KWIT      DELTMX          SMALL          TVARY        NUTS
      5           60        11        0           0     1.00000E 12    1.00000E 00    1.00000E 00      5

    TOTAL TIME       TIME STEP       HEAT FLOW     TEMP FROM FLUX    FLUX RATE       TEMP RATE
   6.11440E 02      2.49350E 00     3.96811E 03     2.92335E 03     6.48977E 00     4.78108E 00

    AVG TEMP      HEAT CAPACITY    HEAT CONTENT      GEN RATE          HEAT GEN        TEMP FROM GEN
   8.72991E 01     1.35739D 00     1.18498E 02     0.0               0.0              0.0
==========================================================================================================

NODE         TEMP          DT            DDT          GE N RATE      W            H            F           CURE AT 280 F
  1       0.9365D 02  -0.2991D-01  -0.6185D-02    0.0          0.3041E-05  -0.6608E-06  -0.1085E-02   0.0
 13       0.9365D 02  -0.2991D-01  -0.6185D-02    0.0          0.3041E-05  -0.6608E-06  -0.1085E-02   0.0
 25       0.9365D 02  -0.2991D-01  -0.6185D-02    0.0          0.3041E-05  -0.6607E-06  -0.1085E-02   0.0
 37       0.9365D 02  -0.2991D-01  -0.6185D-02    0.0          0.3041E-05  -0.6607E-06  -0.1085E-02   0.0
  2       0.9455D 02  -0.9901D-01  -0.2047D-01    0.0          0.7675E 00  -0.1579E 00  -0.1579E 00   0.0
 14       0.9459D 02  -0.9916D-01  -0.2050D-01    0.0          0.7679E 00  -0.1576E 00  -0.1576E 00   0.0
 26       0.9492D 02  -0.9911D-01  -0.2049D-01    0.0          0.7705E 00  -0.1549E 00  -0.1549E 00   0.0
 38       0.9493D 02  -0.9913D-01  -0.2050D-01    0.0          0.7706E 00  -0.1548E 00  -0.1548E 00   0.0
  3       0.9346D 02  -0.9869D-01  -0.2041D-01    0.0          0.2276E 01  -0.5002E 00  -0.5002E 00   0.0
 15       0.9360D 02  -0.9918D-01  -0.2051D-01    0.0          0.2279E 01  -0.4969E 00  -0.4969E 00   0.0
 27       0.9442D 02  -0.9894D-01  -0.2046D-01    0.0          0.2299E 01  -0.4768E 00  -0.4769E 00   0.0
 39       0.9448D 02  -0.9913D-01  -0.2050D-01    0.0          0.2301E 01  -0.4753E 00  -0.4753E 00   0.0
  4       0.9162D 02  -0.9851D-01  -0.2037D-01    0.0          0.3719E 01  -0.9083E 00  -0.9083E 00   0.0
 16       0.9187D 02  -0.9920D-01  -0.2051D-01    0.0          0.3729E 01  -0.8984E 00  -0.8984E 00   0.0
 28       0.9313D 02  -0.9884D-01  -0.2044D-01    0.0          0.3780E 01  -0.8469E 00  -0.8469E 00   0.0
 40       0.9327D 02  -0.9919D-01  -0.2051D-01    0.0          0.3786E 01  -0.8415E 00  -0.8415E 00   0.0
  5       0.8903D 02  -0.9883D-01  -0.2043D-01    0.0          0.5059E 01  -0.1419E 01  -0.1419E 01   0.0
 17       0.8939D 02  -0.9941D-01  -0.2055D-01    0.0          0.5080E 01  -0.1399E 01  -0.1399E 01   0.0
 29       0.9107D 02  -0.9907D-01  -0.2048D-01    0.0          0.5175E 01  -0.1303E 01  -0.1303E 01   0.0
 41       0.9128D 02  -0.9957D-01  -0.2059D-01    0.0          0.5187E 01  -0.1291E 01  -0.1291E 01   0.0
  6       0.8569D 02  -0.9802D-01  -0.2027D-01    0.0          0.6261E 01  -0.2068E 01  -0.2068E 01   0.0
 18       0.8616D 02  -0.9866D-01  -0.2040D-01    0.0          0.6295E 01  -0.2034E 01  -0.2034E 01   0.0
 30       0.8824D 02  -0.9842D-01  -0.2035D-01    0.0          0.6447E 01  -0.1882E 01  -0.1882E 01   0.0
 42       0.8853D 02  -0.9914D-01  -0.2050D-01    0.0          0.6468E 01  -0.1861E 01  -0.1861E 01   0.0
  7       0.8212D 02  -0.8445D-01  -0.1746D-01    0.0          0.5375E 01  -0.2087E 01  -0.2087E 01   0.0
 19       0.8268D 02  -0.8904D-01  -0.1841D-01    0.0          0.5411E 01  -0.2050E 01  -0.2050E 01   0.0
 31       0.8510D 02  -0.8880D-01  -0.1836D-01    0.0          0.5570E 01  -0.1892E 01  -0.1892E 01   0.0
 43       0.8546D 02  -0.9011D-01  -0.1863D-01    0.0          0.5593E 01  -0.1868F 01  -0.1868E 01   0.0
  8       0.8043D 02  -0.6558D-01  -0.1356D-01    0.0          0.5677E 01  -0.2370E 01  -0.2370E 01   0.0
 20       0.8102D 02  -0.7485D-01  -0.1548D-01    0.0          0.5719E 01  -0.2328E 01  -0.2328E 01   0.0
 32       0.8358D 02  -0.7445D-01  -0.1539D-01    0.0          0.5900E 01  -0.2147E 01  -0.2147E 01   0.0
 44       0.8396D 02  -0.7606D-01  -0.1573D-01    0.0          0.5927E 01  -0.2120E 01  -0.2120E 01   0.0
  9       0.7744D 02  -0.4362D-01  -0.9018D-26    0.0          0.8274E-02  -0.3906E-02  -0.3890E-02   0.0
 21       0.7831D 02  -0.5278D-01  -0.1091D-25    0.0          0.8367E-02  -0.3813E-02  -0.3788E-02   0.0
 33       0.8157D 02  -0.5287D-01  -0.1093D-25    0.0          0.8715E-02  -0.3464E-02  -0.3449E-02   0.0
 45       0.8223D 02  -0.5401D-01  -0.1117D-01    0.0          0.8786E-02  -0.3394E-02  -0.3375E-02   0.0
 10       0.7221D 02  -0.1007D 00   -0.2082D-25    0.0          0.8902E-02  -0.5152E-02  -0.5136E-02   0.0
 22       0.7362D 02  -0.6499D-01  -0.1344D-25    0.0          0.9076E-02  -0.4978E-02  -0.4952E-02   0.0
 34       0.7812D 02  -0.6954D-01  -0.1438D-25    0.0          0.9631E-02  -0.4423E-02  -0.4408E-02   0.0
 46       0.7928D 02  -0.6164D-01  -0.1274D-25    0.0          0.9773E-02  -0.4280E-02  -0.4260E-02   0.0
 11       0.6760D 02  -0.3567D 00   -0.7374D-25    0.0          0.8822E-02  -0.6055E-02  -0.6041E-02   0.0
 23       0.6956D 02  -0.1820D 00   -0.3762D-25    0.0          0.9077E-02  -0.5799E-02  -0.5777E-02   0.0
 35       0.7515D 02  -0.1997D 00   -0.4128D-25    0.0          0.9807E-02  -0.5070E-02  -0.5057E-02   0.0
 47       0.7677D 02  -0.1645D 00   -0.3402D-25    0.0          0.1002E-01  -0.4858E-02  -0.4841E-02   0.0

NODE         TEMP          DT            DDT          GE N RATE      W            H            F           CURE AT 280 F
 12       0.6548D 02  -0.6378D 00   -0.1319D-24    0.0          0.2003E-23  -0.1485E-23   0.8892E 03    0.0
 24       0.6774D 02  -0.3189D 00   -0.6593D-25    0.0          0.2073E-23  -0.1415E-23   0.1047E 04    0.0
 36       0.7381D 02  -0.3508D 00   -0.7252D-25    0.0          0.2258E-23  -0.1230E-23   0.8402E 03    0.0
 48       0.7566D 02  -0.2870D 00   -0.5934D-25    0.0          0.2315E-23  -0.1173E-23   0.1228E 04    0.0
==========================================================================================================
  MATERIAL DATA

    NAME  MATL      TOT CAP         TOT HEAT        AVG TEMP        TMELT           HMELT
    SAND    1     1.07359E 00     9.51664E 01     8.86434E 01     0.0             0.0
    STEL    2     2.82356E-01     2.32229E 01     8.22471E 01     0.0             0.0
    AIR     3     1.44246E-03     1.09248E-01     7.57377E 01     0.0             0.0
  ====================------------------------------------------------------------------------------
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TRUMP OUTPUT DATA                                                                          DATA DECK    1
 *   MISSLE PROBLEM    TWO DIMENSIONAL
=====================================================================================================================
   PRINTOUT     CYCLE    TOO FAST   TOO SLOW     KWIT      DELTMX          SMALL           TVARY         NUTS
      6           80         11         0          0      1.00000E 12     1.00000E 00     1.00000E 00      4

    TOTAL TIME      TIME STEP       HEAT FLOW     TEMP FROM FLUX    FLUX RATE       TEMP RATE
   7.17775E 02     5.98896E 00    -2.17843E 04   -1.60488E 04    -3.03498E 01    -2.23590E 01

    AVG TEMP      HEAT CAPACITY    HEAT CONTENT     GEN RATE         HEAT GEN       TEMP FROM GEN
   8.53896E 01     1.35739D 00     1.15907E 02     0.0              0.0             0.0
=====================================================================================================================

 NODE        TEMP           DT             DDT          GE N RATE        W             H              F          CURE AT 280 F
   1      0.9217D 02  -0.3109D 00   -0.5175D-01    0.0           0.2993E-05  -0.7087E-06   -0.1238E-02    0.0
  13      0.9217D 02  -0.3109D 00   -0.5176D-01    0.0           0.2993E-05  -0.7087E-06   -0.1238E-02    0.0
  25      0.9217D 02  -0.3109D 00   -0.5176D-01    0.0           0.2993E-05  -0.7087E-06   -0.1238E-02    0.0
  37      0.9217D 02  -0.3109D 00   -0.5176D-01    0.0           0.2993E-05  -0.7087E-06   -0.1238E-02    0.0
   2      0.9045D 02  -0.2147D 00   -0.3574D-01    0.0           0.7343E 00  -0.1912E 00   -0.1912E 00    0.0
  14      0.9047D 02  -0.2167D 00   -0.3608D-01    0.0           0.7345E 00  -0.1910E 00   -0.1910E 00    0.0
  26      0.9080D 02  -0.2175D 00   -0.3621D-01    0.0           0.7371E 00  -0.1883E 00   -0.1884E 00    0.0
  38      0.9081D 02  -0.2170D 00   -0.3613D-01    0.0           0.7372E 00  -0.1882E 00   -0.1883E 00    0.0
   3      0.8945D 02  -0.1989D 00   -0.3312D-01    0.0           0.2178E 01  -0.5978E 00   -0.5978E 00    0.0
  15      0.8954D 02  -0.2064D 00   -0.3436D-01    0.0           0.2181E 01  -0.5958E 00   -0.5958E 00    0.0
  27      0.9036D 02  -0.2075D 00   -0.3454D-01    0.0           0.2201E 01  -0.5758E 00   -0.5758E 00    0.0
  39      0.9042D 02  -0.2072D 00   -0.3449D-01    0.0           0.2202E 01  -0.5743E 00   -0.5743E 00    0.0
   4      0.8787D 02  -0.1633D 00   -0.2719D-01    0.0           0.3566E 01  -0.1061E 01   -0.1061E 01    0.0
  16      0.8799D 02  -0.1804D 00   -0.3003D-01    0.0           0.3571E 01  -0.1056E 01   -0.1056E 01    0.0
  28      0.8925D 02  -0.1820D 00   -0.3030D-01    0.0           0.3623E 01  -0.1004E 01   -0.1004E 01    0.0
  40      0.8937D 02  -0.1821D 00   -0.3031D-01    0.0           0.3628E 01  -0.9995E 00   -0.9995E 00    0.0
   5      0.8587D 02  -0.9557D-01   -0.1591D-01    0.0           0.4880E 01  -0.1598E 01   -0.1598E 01    0.0
  17      0.8595D 02  -0.1297D 00   -0.2160D-01    0.0           0.4884E 01  -0.1594E 01   -0.1594E 01    0.0
  29      0.8762D 02  -0.1325D 00   -0.2206D-01    0.0           0.4979E 01  -0.1499E 01   -0.1499E 01    0.0
  41      0.8781D 02  -0.1329D 00   -0.2212D-01    0.0           0.4990E 01  -0.1488E 01   -0.1488E 01    0.0
   6      0.8381D 02   0.1839D-01    0.3061D-02    0.0           0.6123E 01  -0.2206E 01   -0.2206E 01    0.0
  18      0.8367D 02  -0.4396D-01   -0.7318D-02    0.0           0.6113E 01  -0.2216E 01   -0.2216E 01    0.0
  30      0.8572D 02  -0.4903D-01   -0.8162D-02    0.0           0.6263E 01  -0.2066E 01   -0.2066E 01    0.0
  42      0.8598D 02  -0.4940D-01   -0.8224D-02    0.0           0.6282E 01  -0.2047E 01   -0.2047E 01    0.0
   7      0.8245D 02   0.1662D 00    0.2766D-01    0.0           0.5396E 01  -0.2065E 01   -0.2065E 01    0.0
  19      0.8184D 02   0.6787D-01    0.1130D-01    0.0           0.5356E 01  -0.2105E 01   -0.2105E 01    0.0
  31      0.8420D 02   0.5945D-01    0.9897D-02    0.0           0.5511E 01  -0.1951E 01   -0.1951E 01    0.0
  43      0.8451D 02   0.5951D-01    0.9908D-02    0.0           0.5531E 01  -0.1930E 01   -0.1930E 01    0.0
   8      0.8223D 02   0.2441D 00    0.4064D-01    0.0           0.5804E 01  -0.2243E 01   -0.2243E 01    0.0
  20      0.8126D 02   0.1269D 00    0.2113D-01    0.0           0.5736E 01  -0.2311E 01   -0.2311E 01    0.0
  32      0.8374D 02   0.1166D 00    0.1941D-01    0.0           0.5911E 01  -0.2136E 01   -0.2136E 01    0.0
  44      0.8408D 02   0.1170D 00    0.1948D-01    0.0           0.5935E 01  -0.2112E 01   -0.2112E 01    0.0
   9      0.8248D 02   0.3984D 00    0.6632D-01    0.0           0.8812E-02  -0.3368E-02   -0.3269E-02    0.0
  21      0.8036D 02   0.2063D 00    0.3435D-01    0.0           0.8586E-02  -0.3594E-02   -0.3523E-02    0.0
  33      0.8371D 02   0.2066D 00    0.3440D-01    0.0           0.8944E-02  -0.3236E-02   -0.3174E-02    0.0
  45      0.8400D 02   0.1884D 00    0.3136D-01    0.0           0.8975E-02  -0.3205E-02   -0.3145E-02    0.0
  10      0.8293D 02   0.6658D 00    0.1108D 00    0.0           0.1022E-01  -0.3830E-02   -0.3710E-02    0.0
  22      0.7879D 02   0.3407D 00    0.5672D-01    0.0           0.9713E-02  -0.4340E-02   -0.4258E-02    0.0
  34      0.8370D 02   0.3610D 00    0.6010D-01    0.0           0.1032E-01  -0.3735E-02   -0.3662E-02    0.0
  46      0.8390D 02   0.3086D 00    0.5138D-01    0.0           0.1034E-01  -0.3711E-02   -0.3639E-02    0.0
  11      0.8339D 02   0.8966D 00    0.1493D 00    0.0           0.1088E-01  -0.3995E-02   -0.3894E-02    0.0
  23      0.7742D 02   0.4522D 00    0.7528D-01    0.0           0.1010E-01  -0.4773E-02   -0.4704E-02    0.0
  35      0.8375D 02   0.4922D 00    0.8194D-01    0.0           0.1093E-01  -0.3948E-02   -0.3886E-02    0.0
  47      0.8384D 02   0.4078D 00    0.6789D-01    0.0           0.1094E-01  -0.3935E-02   -0.3875E-02    0.0

 NODE        TEMP           DT             DDT          GE N RATE        W             H              F          CURE AT 280 F
  12      0.8363D 02   0.9969D 00    0.1660D 00    0.0           0.2559E-23  -0.9292E-24   -0.9410E 04    0.0
  24      0.7681D 02   0.4984D 00    0.8298D-01    0.0           0.2350E-23  -0.1138E-23   -0.4104E 04    0.0
  36      0.8380D 02   0.5483D 00    0.9127D-01    0.0           0.2564E-23  -0.9241E-24   -0.4825E 04    0.0
  48      0.8383D 02   0.4486D 00    0.7468D-01    0.0           0.2565E-23  -0.9230E-24   -0.3407E 04    0.0
=====================================================================================================================
  MATERIAL DATA

    NAME   MATL      TOT CAP         TOT HEAT        AVG TEMP        TMELT          HMELT
    SAND     1     1.07359E 00     9.24010E 01     8.60675E 01     0.0            0.0
    STEL     2     2.82356E-01     2.33869E 01     8.28278E 01     0.0            0.0
    AIR      3     1.44246E-03     1.18769E-01     8.23378E 01     0.0            0.0
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TRUMP OUTPUT DATA                                                                      DATA DECK    1
 *   MISSLE PROBLEM    TWO DIMENSIONAL
==========================================================================================================

  PRINTOUT     CYCLE    TOO FAST  TOO SLOW     KWIT     DELTMX          SMALL            TVARY        NUTS
     7          100        11         0          0    1.00000E 12    1.00000E 00    1.00000E 00      3

   TOTAL TIME      TIME STEP       HEAT FLOW      TEMP FROM FLUX   FLUX RATE       TEMP RATE
  7.84895E 02     3.24344E 00    -2.06335E 04    -1.52009E 04    -2.62882E 01    -1.93668E 01

    AVG TEMP      HEAT CAPACITY    HEAT CONTENT     GEN RATE          HEAT GEN        TEMP FROM GEN
  8.62263E 01     1.357390 00     1.17042E 02     0.0               0.0             0.0
==========================================================================================================

NODE        TEMP           DT            DDT          GE N RATE        W            H             F          CURE AT 280 F
  1      0.8729D 02   -0.1909D 00   -0.5887D-01    0.0           0.2834E-05  -0.8673E-06  -0.1267E-02    0.0
 13      0.8729D 02   -0.1910D 00   -0.5887D-01    0.0           0.2834E-05  -0.8673E-06  -0.1267E-02    0.0
 25      0.8729D 02   -0.1910D 00   -0.5887D-01    0.0           0.2834E-05  -0.8673E-06  -0.1267E-02    0.0
 37      0.8729D 02   -0.1910D 00   -0.5887D-01    0.0           0.2834E-05  -0.8673E-06  -0.1267E-02    0.0
  2      0.8838D 02   -0.8224D-01   -0.2535D-01    0.0           0.7174E 00  -0.2080E 00  -0.2080E 00    0.0
 14      0.8836D 02   -0.8525D-01   -0.2628D-01    0.0           0.7173E 00  -0.2081E 00  -0.2081E 00    0.0
 26      0.8867D 02   -0.8680D-01   -0.2676D-01    0.0           0.7198E 00  -0.2056E 00  -0.2057E 00    0.0
 38      0.8869D 02   -0.8565D-01   -0.2641D-01    0.0           0.7200E 00  -0.2054E 00  -0.2055E 00    0.0
  3      0.8767D 02   -0.6371D-01   -0.1964D-01    0.0           0.2135E 01  -0.6413E 00  -0.6413E 00    0.0
 15      0.8761D 02   -0.7383D-01   -0.2276D-01    0.0           0.2134E 01  -0.6428E 00  -0.6428E 00    0.0
 27      0.8839D 02   -0.7691D-01   -0.2371D-01    0.0           0.2153E 01  -0.6236E 00  -0.6236E 00    0.0
 39      0.8847D 02   -0.7499D-01   -0.2312D-01    0.0           0.2155E 01  -0.6217E 00  -0.6217E 00    0.0
  4      0.8665D 02   -0.2764D-01   -0.8521D-02    0.0           0.3517E 01  -0.1110E 01  -0.1110E 01    0.0
 16      0.8647D 02   -0.4857D-01   -0.1498D-01    0.0           0.3510E 01  -0.1117E 01  -0.1117E 01    0.0
 28      0.8768D 02   -0.5411D-01   -0.1668D-01    0.0           0.3559E 01  -0.1068E 01  -0.1068E 01    0.0
 40      0.8782D 02   -0.5094D-01   -0.1570D-01    0.0           0.3565E 01  -0.1062F 01  -0.1062E 01    0.0
  5      0.8567D 02    0.3470D-01    0.1070D-01    0.0           0.4868E 01  -0.1610E 01  -0.1610E 01    0.0
 17      0.8517D 02   -0.4128D-02   -0.1273D-02    0.0           0.4840E 01  -0.1638E 01  -0.1638E 01    0.0
 29      0.8674D 02   -0.1521D-01   -0.4689D-02    0.0           0.4929E 01  -0.1549E 01  -0.1549E 01    0.0
 41      0.8697D 02   -0.8738D-02   -0.2694D-02    0.0           0.4942E 01  -0.1536E 01  -0.1536E 01    0.0
  6      0.8529D 02    0.1358D 00    0.4186D-01    0.0           0.6231E 01  -0.2097E 01  -0.2097E 01    0.0
 18      0.8411D 02    0.6716D-01    0.2071D-01    0.0           0.6145E 01  -0.2184E 01  -0.2184E 01    0.0
 30      0.8593D 02    0.4415D-01    0.1361D-01    0.0           0.6278E 01  -0.2051E 01  -0.2051E 01    0.0
 42      0.8631D 02    0.5833D-01    0.1799D-01    0.0           0.6306E 01  -0.2023E 01  -0.2023E 01    0.0
  7      0.8631D 02    0.2692D 00    0.8300D-01    0.0           0.5649E 01  -0.1812E 01  -0.1812E 01    0.0
 19      0.8396D 02    0.1597D 00    0.4924D-01    0.0           0.5495E 01  -0.1966E 01  -0.1966E 01    0.0
 31      0.8581D 02    0.1174D 00    0.3619D-01    0.0           0.5616E 01  -0.1845E 01  -0.1845E 01    0.0
 43      0.8642D 02    0.1446D 00    0.4457D-01    0.0           0.5656E 01  -0.1805E 01  -0.1805E 01    0.0
  8      0.8755D 02    0.3419D 00    0.1054D 00    0.0           0.6180E 01  -0.1867E 01  -0.1867E 01    0.0
 20      0.8439D 02    0.2095D 00    0.6458D-01    0.0           0.5957E 01  -0.2090E 01  -0.2090E 01    0.0
 32      0.8614D 02    0.1557D 00    0.4800D-01    0.0           0.6080E 01  -0.1967E 01  -0.1967E 01    0.0
 44      0.8692D 02    0.1906D 00    0.5877D-01    0.0           0.6136E 01  -0.1911E 01  -0.1911E 01    0.0
  9      0.9084D 02    0.4750D 00    0.1465D 00    0.0           0.9705E-02  -0.2475E-02  -0.2338E-02    0.0
 21      0.8503D 02    0.2737D 00    0.8437D-01    0.0           0.9084E-02  -0.3096E-02  -0.3003E-02    0.0
 33      0.8723D 02    0.2027D 00    0.6250D-01    0.0           0.9320E-02  -0.2860E-02  -0.2785E-02    0.0
 45      0.8811D 02    0.2424D 00    0.7474D-01    0.0           0.9413E-02  -0.2766E-02  -0.2686E-02    0.0
 10      0.9660D 02    0.7078D 00    0.2182D 00    0.0           0.1191E-01  -0.2145E-02  -0.1977E-02    0.0
 22      0.8607D 02    0.3831D 00    0.1181D 00    0.0           0.1061F-01  -0.3443E-02  -0.3332E-02    0.0
 34      0.8915D 02    0.2827D 00    0.8716D-01    0.0           0.1099E-01  -0.3064E-02  -0.2975E-02    0.0
 46      0.9015D 02    0.3299D 00    0.1017D 00    0.0           0.1111E-01  -0.2940F-02  -0.2844E-02    0.0
 11      0.1017D 03    0.9101D 00    0.2806D 00    0.0           0.1327E-01  -0.1606E-02  -0.1463E-02    0.0
 23      0.8692D 02    0.4746D 00    0.1463D 00    0.0           0.1134E-01  -0.3533E-02  -0.3439E-02    0.0
 35      0.9082D 02    0.3497D 00    0.1078D 00    0.0           0.1185E-01  -0.3025E-02  -0.2950E-02    0.0
 47      0.9189D 02    0.4022D 00    0.1240D 00    0.0           0.1199E-01  -0.2885E-02  -0.2804E-02    0.0

NODF        TEMP           DT            DDT          GE N RATE        W            H             F          CURE AT 280 F
 12      0.1040D 03    0.1000D 01    0.3083D 00    0.0           0.3182E-23  -0.3057E-24  -0.8867E 04    0.0
 24      0.8728D 02    0.5135D 00    0.1583D 00    0.0           0.2670E-23  -0.8177E-24  -0.3816E 04    0.0
 36      0.9157D 02    0.3784D 00    0.1167D 00    0.0           0.2802E-23  -0.6862E-24  -0.4729E 04    0.0
 48      0.9265D 02    0.4325D 00    0.1333D 00    0.0           0.2835E-23  -0.6531E-24  -0.3184E 04    0.0
==========================================================================================================
   MATERIAL DATA

    NAMF   MATL      TOT CAP         TOT HEAT        AVG TEMP        TMELT          HMELT
    SAND     1     1.07359E 00     9.25579F 01     8.62137E 01     0.0            0.0
    STFL     2     2.82356E-01     2.43540E 01     8.62529E 01     0.0            0.0
    AIR      3     1.44246F-03     1.30603F-01     9.05417E 01     0.0            0.0
    ==================================================================================
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TRUMP OUTPUT DATA                                                                                   DATA DECK    1

 *   MISSLE PROBLEM    TWO DIMENSIONAL
==================================================================================================================

  PRINTOUT     CYCLE    TOO FAST   TOO SLOW      KWIT      DELTMX           SMALL            TVARY          NUTS
     8          120        11          0           0     1.00000E 12     1,00000E 00     1.00000E 00       3

   TOTAL TIME       TIME STEP       HEAT FLOW     TEMP FROM FLUX   FLUX RATE      TEMP RATE
  8.51641E 02     4.38834E 00    -2.30600E 04    -1.69885E 04   -2.70771E 01   -1.99480E 01

    AVG TEMP       HEAT CAPACITY    HEAT CONTENT     GEN RATE          HEAT GEN        TEMP FROM GEN
  8.88432E 01      1.35739D 00     1.20594E 02     0.0                0.0              0.0
==================================================================================================================

NODE         TEMP           DT            DDT           GE N RATE        W             H             F          CURE AT 280 F
   1      0.8720D 02    0.8892D-01    0.2026D-01     0.0            0.2832E-05   -0.8702E-06   -0.1147E-02      0.0
  13      0.8720D 02    0.8890D-01    0.2026D-01     0.0            0.2831E-05   -0.8703E-06   -0.1147E-02      0.0
  25      0.8720D 02    0.8888D-01    0.2025D-01     0.0            0.2832E-05   -0.8702E-06   -0.1147E-02      0.0
  37      0.8720D 02    0.8890D-01    0.2026D-01     0.0            0.2832E-05   -0.8702E-06   -0.1147E-02      0.0
   2      0.8726D 02   -0.3531D-01   -0.8046D-02     0.0            0.7084E 00   -0.2170E 00   -0.2171E 00      0.0
  14      0.8715D 02   -0.4372D-01   -0.9963D-02     0.0            0.7075E 00   -0.2180E 00   -0.2180E 00      0.0
  26      0.8740D 02   -0.4947D-01   -0.1127D-01     0.0            0.7095E 00   -0.2160E 00   -0.2160E 00      0.0
  38      0.8747D 02   -0.4507D-01   -0.1027D-01     0.0            0.7100E 00   -0.2154E 00   -0.2154E 00      0.0
   3      0.8705D 02    0.4146D-02    0.9447D-27     0.0            0.2120E 01   -0.6564E 00   -0.6564E 00      0.0
  15      0.8668D 02   -0.2253D-01   -0.5134D-02     0.0            0.2111E 01   -0.6654E 00   -0.6654E 00      0.0
  27      0.8734D 02   -0.3563D-01   -0.8120D-02     0.0            0.2127E 01   -0.6494E 00   -0.6494E 00      0.0
  39      0.8750D 02   -0.2635D-01   -0.6004D-02     0.0            0.2131E 01   -0.6453E 00   -0.6453E 00      0.0
   4      0.8697D 02    0.7579D-01    0.1727D-01     0.0            0.3530E 01   -0.1097E 01   -0.1097E 01      0.0
  16      0.8617D 02    0.2430D-01    0.5538D-02     0.0            0.3498E 01   -0.1129E 01   -0.1129E 01      0.0
  28      0.8715D 02    0.1715D-02    0.3908D-27     0.0            0.3537E 01   -0.1090E 01   -0.1090E 01      0.0
  40      0.8745D 02    0.1707D-01    0.3890D-02     0.0            0.3549E 01   -0.1078E 01   -0.1078E 01      0.0
   5      0.8752D 02    0.1871D 00    0.4263D-01     0.0            0.4973E 01   -0.1505E 01   -0.1505E 01      0.0
  17      0.8594D 02    0.1003D 00    0.2286D-01     0.0            0.4883E 01   -0.1595E 01   -0.1595E 01      0.0
  29      0.8710D 02    0.6297D-01    0.1435D-01     0.0            0.4949E 01   -0.1529E 01   -0.1529E 01      0.0
  41      0.8760D 02    0.8793D-01    0.2004D-01     0.0            0.4978E 01   -0.1500E 01   -0.1500E 01      0.0
   6      0.8943D 02    0.3433D 00    0.7824D-01     0.0            0.6533E 01   -0.1795E 01   -0.1795E 01      0.0
  18      0.8647D 02    0.2084D 00    0.4748D-01     0.0            0.6317E 01   -0.2011E 01   -0.2011E 01      0.0
  30      0.8757D 02    0.1484D 00    0.3382D-01     0.0            0.6398E 01   -0.1931E 01   -0.1931E 01      0.0
  42      0.8842D 02    0.1881D 00    0.4287D-01     0.0            0.6460E 01   -0.1869E 01   -0.1869E 01      0.0
   7      0.9320D 02    0.5097D 00    0.1161D 00     0.0            0.6100E 01   -0.1361E 01   -0.1361E 01      0.0
  19      0.8823D 02    0.3279D 00    0.7472D-01     0.0            0.5774E 01   -0.1687E 01   -0.1687E 01      0.0
  31      0.8894D 02    0.2380D 00    0.5424D-01     0.0            0.5821E 01   -0.1640E 01   -0.1640E 01      0.0
  43      0.9030D 02    0.2955D 00    0.6734D-01     0.0            0.5910E 01   -0.1551E 01   -0.1551E 01      0.0
   8      0.9582D 02    0.5702D 00    0.1299D 00     0.0            0.6764E 01   -0.1283E 01   -0.1283E 01      0.0
  20      0.8962D 02    0.3803D 00    0.8666D-01     0.0            0.6326E 01   -0.1721E 01   -0.1721E 01      0.0
  32      0.9000D 02    0.2706D 00    0.6167D-01     0.0            0.6353E 01   -0.1694E 01   -0.1694E 01      0.0
  44      0.9167D 02    0.3367D 00    0.7673D-01     0.0            0.6471E 01   -0.1576E 01   -0.1576E 01      0.0
   9      0.1014D 03    0.6600D 00    0.1504D 00     0.0            0.1083E-01   -0.1350E-02   -0.1198E-02      0.0
  21      0.9134D 02    0.4427D 00    0.1009D 00     0.0            0.9759E-02   -0.2421E-02   -0.2313E-02      0.0
  33      0.9181D 02    0.2859D 00    0.6516D-01     0.0            0.9809E-02   -0.2370E-02   -0.2289E-02      0.0
  45      0.9366D 02    0.3624D 00    0.8259D-01     0.0            0.1001E-01   -0.2173E-02   -0.2084E-02      0.0
  10      0.1111D 03    0.7936D 00    0.1809D 00     0.0            0.1369E-01   -0.3596E-03   -0.1743E-03      0.0
  22      0.9425D 02    0.5351D 00    0.1219D 00     0.0            0.1162E-01   -0.2435E-02   -0.2306E-02      0.0
  34      0.9494D 02    0.3001D 00    0.6839D-01     0.0            0.1170E-01   -0.2350E-02   -0.2253E-02      0.0
  46      0.9704D 02    0.3927D 00    0.8948D-01     0.0            0.1196E-01   -0.2091E-02   -0.1984E-02      0.0
  11      0.1196D 03    0.8910D 00    0.2030D 00     0.0            0.1561E-01    0.7310E-03    0.8884E-03      0.0
  23      0.9664D 02    0.6010D 00    0.1370D 00     0.0            0.1261E-01   -0.2265E-02   -0.2155E-02      0.0
  35      0.9761D 02    0.3020D 00    0.6881D-01     0.0            0.1274E-01   -0.2139E-02   -0.2058E-02      0.0
  47      0.9987D 02    0.4065D 00    0.9263D-01     0.0            0.1303E-01   -0.1844E-02   -0.1754E-02      0.0

NODE         TEMP           DT            DDT           GE N RATE        W             H             F          CURE AT 280 F
  12      0.1234D 03    0.9142D 00    0.2083D 00     0.0            0.3776E-23    0.2884E-24   -0.1003E 05      0.0
  24      0.9765D 02    0.6217D 00    0.1417D 00     0.0            0.2988E-23   -0.5002E-24   -0.4017E 04      0.0
  36      0.9878D 02    0.2926D 00    0.6667D-01     0.0            0.3022E-23   -0.4658E-24   -0.5309E 04      0.0
  48      0.1011D 03    0.4023D 00    0.9167D-01     0.0            0.3092E-23   -0.3957E-24   -0.3669E 04      0.0
==================================================================================================================
   MATERIAL DATA

     NAME   MATL      TOT CAP          TOT HEAT        AVG TEMP        TMELT           HMELT
     SAND     1     1.07359E 00     9.45373E 01     8.80574E 01     0.0             0.0
     STEL     2     2.82356E-01     2.59139E 01     9.17777E 01     0.0             0.0
     AIR      3     1.44246E-03     1.43372E-01     9.93947E 01     0.0             0.0
   ===========================================================-------------------------------------------
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TRUMP OUTPUT DATA                                                                                      DATA DECK    1
  *   MISSLE PROBLEM    TWO DIMENSIONAL
=====================================================================================================================
    PRINTOUT     CYCLE   TOO FAST  TOO SLOW      KWIT      DELTMX           SMALL              TVARY         NUTS
        9         140       11         0           0     1.00000E 12     1.00000E 00      1.00000E 00      3

      TOTAL TIME       TIME STEP       HEAT FLOW      TEMP FROM FLUX    FLUX RATE        TEMP RATE
     9.47229E 02     4.80006E 00    -2.34107E 04     -1.72469E 04    -2.47150E 01     -1.82078E 01

      AVG TEMP       HEAT CAPACITY    HEAT CONTENT      GEN RATE          HEAT GEN         TEMP FROM GEN
     9.43739E 01     1.35739D 00     1.28102E 02     0.0               0.0               0.0
=====================================================================================================================

 NODE        TEMP          DT           DDT          GE N RATE         W            H             F          CURE AT 280 F
    1     0.8785D 02  -0.3074D-01  -0.6404D-02    0.0            0.2853E-05  -0.8492E-06  -0.1220E-02    0.0
   13     0.8785D 02  -0.3077D-01  -0.6411D-02    0.0            0.2853E-05  -0.8492E-06  -0.1220E-02    0.0
   25     0.8785D 02  -0.3081D-01  -0.6419D-02    0.0            0.2853E-05  -0.8492E-06  -0.1220E-02    0.0
   37     0.8785D 02  -0.3078D-01  -0.6413D-02    0.0            0.2853E-05  -0.8492E-06  -0.1220E-02    0.0
    2     0.8800D 02   0.1048D 00   0.2182D-01    0.0            0.7144E 00  -0.2111E 00  -0.2111E 00    0.0
   14     0.8763D 02   0.9009D-01   0.1877D-01    0.0            0.7114E 00  -0.2140E 00  -0.2140E 00    0.0
   26     0.8768D 02   0.7680D-01   0.1600D-01    0.0            0.7118E 00  -0.2136E 00  -0.2137E 00    0.0
   38     0.8790D 02   0.8629D-01   0.1798D-01    0.0            0.7136E 00  -0.2119E 00  -0.2119E 00    0.0
    3     0.8880D 02   0.1592D 00   0.3316D-01    0.0            0.2163E 01  -0.6137E 00  -0.6137E 00    0.0
   15     0.8767D 02   0.1162D 00   0.2421D-01    0.0            0.2135E 01  -0.6412E 00  -0.6412E 00    0.0
   27     0.8786D 02   0.8430D-01   0.1756D-01    0.0            0.2140E 01  -0.6366E 00  -0.6366E 00    0.0
   39     0.8835D 02   0.1056D 00   0.2200D-01    0.0            0.2152E 01  -0.6246E 00  -0.6246E 00    0.0
    4     0.9038D 02   0.2405D 00   0.5010D-01    0.0            0.3669E 01  -0.9585E 00  -0.9585E 00    0.0
   16     0.8822D 02   0.1676D 00   0.3491D-01    0.0            0.3581E 01  -0.1046E 01  -0.1046E 01    0.0
   28     0.8843D 02   0.1157D 00   0.2410D-01    0.0            0.3589E 01  -0.1038E 01  -0.1038E 01    0.0
   40     0.8924D 02   0.1480D 00   0.3084D-01    0.0            0.3622E 01  -0.1005E 01  -0.1005E 01    0.0
    5     0.9323D 02   0.3458D 00   0.7204D-01    0.0            0.5298E 01  -0.1180E 01  -0.1180E 01    0.0
   17     0.8960D 02   0.2423D 00   0.5049D-01    0.0            0.5091E 01  -0.1387E 01  -0.1387E 01    0.0
   29     0.8956D 02   0.1653D 00   0.3443D-01    0.0            0.5089E 01  -0.1389E 01  -0.1389E 01    0.0
   41     0.9080D 02   0.2098D 00   0.4372D-01    0.0            0.5160E 01  -0.1318E 01  -0.1318E 01    0.0
    6     0.9798D 02   0.4688D 00   0.9767D-01    0.0            0.7158E 01  -0.1171E 01  -0.1170E 01    0.0
   18     0.9223D 02   0.3362D 00   0.7004D-01    0.0            0.6738E 01  -0.1590E 01  -0.1590E 01    0.0
   30     0.9153D 02   0.2267D 00   0.4722D-01    0.0            0.6687E 01  -0.1642E 01  -0.1642E 01    0.0
   42     0.9342D 02   0.2850D 00   0.5938D-01    0.0            0.6826E 01  -0.1503E 01  -0.1503E 01    0.0
    7     0.1044D 03   0.5854D 00   0.1220D 00    0.0            0.6834E 01  -0.6272E 00  -0.6270E 00    0.0
   19     0.9612D 02   0.4297D 00   0.8952D-01    0.0            0.6291E 01  -0.1170E 01  -0.1170E 01    0.0
   31     0.9430D 02   0.2851D 00   0.5939D-01    0.0            0.6172E 01  -0.1289E 01  -0.1289E 01    0.0
   43     0.9702D 02   0.3565D 00   0.7428D-01    0.0            0.6350E 01  -0.1112E 01  -0.1111E 01    0.0
    8     0.1081D 03   0.6373D 00   0.1328D 00    0.0            0.7632E 01  -0.4149E 00  -0.4146E 00    0.0
   20     0.9845D 02   0.4719D 00   0.9832D-01    0.0            0.6949E 01  -0.1098E 01  -0.1097E 01    0.0
   32     0.9592D 02   0.3103D 00   0.6465D-01    0.0            0.6771E 01  -0.1276E 01  -0.1276E 01    0.0
   44     0.9909D 02   0.3876D 00   0.8075D-01    0.0            0.6995E 01  -0.1053E 01  -0.1052E 01    0.0
    9     0.1152D 03   0.7090D 00   0.1477D 00    0.0            0.1231E-01   0.1256E-03   0.2765E-03    0.0
   21     0.1012D 03   0.5151D 00   0.1073D 00    0.0            0.1081E-01  -0.1373E-02  -0.1259E-02    0.0
   33     0.9787D 02   0.3144D 00   0.6549D-01    0.0            0.1046E-01  -0.1723E-02  -0.1641E-02    0.0
   45     0.1014D 03   0.4001D 00   0.8336D-01    0.0            0.1083E-01  -0.1348E-02  -0.1257E-02    0.0
   10     0.1276D 03   0.8366D 00   0.1743D 00    0.0            0.1573E-01   0.1674E-02   0.1857E-02    0.0
   22     0.1057D 03   0.5893D 00   0.1228D 00    0.0            0.1303E-01  -0.1019E-02  -0.8844E-03    0.0
   34     0.1012D 03   0.3189D 00   0.6644D-01    0.0            0.1247E-01  -0.1580E-02  -0.1484E-02    0.0
   46     0.1053D 03   0.4198D 00   0.8746D-01    0.0            0.1298E-01  -0.1076E-02  -0.9686E-03    0.0
   11     0.1385D 03   0.9493D 00   0.1978D 00    0.0            0.1807E-01   0.3191E-02   0.3346E-02    0.0
   23     0.1096D 03   0.6525D 00   0.1359D 00    0.0            0.1430E-01  -0.5790E-03  -0.4654E-03    0.0
   35     0.1040D 03   0.3204D 00   0.6675D-01    0.0            0.1357E-01  -0.1311E-02  -0.1230E-02    0.0
   47     0.1085D 03   0.4346D 00   0.9053D-01    0.0            0.1416E-01  -0.7201E-03  -0.6297E-03    0.0

 NODE        TEMP          DT           DDT          GE N RATE         W            H             F          CURE AT 280 F
   12     0.1433D 03   0.1000D 01   0.2083D 00    0.0            0.4386E-23   0.8977E-24  -0.1018E 05    0.0
   24     0.1112D 03   0.6800D 00   0.1417D 00    0.0            0.3402E-23  -0.8593E-25  -0.4116E 04    0.0
   36     0.1051D 03   0.3200D 00   0.6667D-01    0.0            0.3217E-23  -0.2708E-24  -0.5356E 04    0.0
   48     0.1098D 03   0.4400D 00   0.9167D-01    0.0            0.3360E-23  -0.1276E-24  -0.3734E 04    0.0
=====================================================================================================================
    MATERIAL DATA

      NAME   MATL      TOT CAP          TOT HEAT         AVG TEMP        TMELT            HMELT
      SAND     1     1.07359E 00     9.95961E 01     9.27694E 01     0.0              0.0
      STEL     2     2.82356E-01     2.83471E 01     1.00395E 02     0.0              0.0
      AIR      3     1.44246E-03     1.58701E-01     1.10022E 02     0.0              0.0
    ==================================================================================================
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TRUMP OUTPUT DATA                                                                    DATA DECK    1
 *   MISSLE PROBLEM    TWO DIMENSIONAL
==================================================================================================

  PRINTOUT    CYCLE   TOO FAST  TOO SLOW     KWIT     DELTMX          SMALL          TVARY      NUTS
    10         160       11        0          0     1.00000E 12    1.00000E 00    1.00000E 00    3

    TOTAL TIME     TIME STEP      HEAT FLOW     TEMP FROM FLUX   FLUX RATE      TEMP RATE
   1.06258E 03    6.00003E 00   -2.49402E 04   -1.83737E 04   -2.34713E 01   -1.72915E 01

    AVG TEMP     HEAT CAPACITY   HEAT CONTENT    GEN RATE         HEAT GEN       TEMP FROM GEN
   1.02454F 02     1.35739D 00   1.39070E 02    0.0              0.0            0.0
==================================================================================================

NODE        TEMP         DT           DDT          GE N RATE       W           H            F          CURE AT 280 F
  1       0.9020D 02   0.3238D 00   0.5396D-01    0.0         0.2929E-05  -0.7728E-06  -0.9995E-03    0.0
 13       0.9020D 02   0.3237D 00   0.5396D-01    0.0         0.2929E-05  -0.7728E-06  -0.9995E-03    0.0
 25       0.9020D 02   0.3237D 00   0.5395D-01    0.0         0.2929E-05  -0.7729E-06  -0.9995E-03    0.0
 37       0.9020D 02   0.3237D 00   0.5395D-01    0.0         0.2929E-05  -0.7728E-06  -0.9995E-03    0.0
  2       0.9235D 02   0.3007D 00   0.5012D-01    0.0         0.7497E 00  -0.1757E 00  -0.1757E 00    0.0
 14       0.9164D 02   0.2858D 00   0.4763D-01    0.0         0.7439E 00  -0.1815E 00  -0.1815E 00    0.0
 26       0.9129D 02   0.2624D 00   0.4373D-01    0.0         0.7411E 00  -0.1843E 00  -0.1843E 00    0.0
 38       0.9176D 02   0.2752D 00   0.4587D-01    0.0         0.7449E 00  -0.1805E 00  -0.1805E 00    0.0
  3       0.9438D 02   0.3543D 00   0.5906D-01    0.0         0.2298E 01  -0.4779E 00  -0.4779E 00    0.0
 15       0.9228D 02   0.3155D 00   0.5259D-01    0.0         0.2247E 01  -0.5291E 00  -0.5291E 00    0.0
 27       0.9148D 02   0.2556D 00   0.4259D-01    0.0         0.2228E 01  -0.5484E 00  -0.5484E 00    0.0
 39       0.9256D 02   0.2867D 00   0.4779D-01    0.0         0.2254E 01  -0.5222E 00  -0.5222E 00    0.0
  4       0.9763D 02   0.4192D 00   0.6986D-01    0.0         0.3963E 01  -0.6646E 00  -0.6646E 00    0.0
 16       0.9394D 02   0.3677D 00   0.6127D-01    0.0         0.3813E 01  -0.8141E 00  -0.8141E 00    0.0
 28       0.9256D 02   0.2707D 00   0.4511D-01    0.0         0.3757E 01  -0.8703E 00  -0.8703E 00    0.0
 40       0.9424D 02   0.3172D 00   0.5287D-01    0.0         0.3825E 01  -0.8020E 00  -0.8020E 00    0.0
  5       0.1024D 03   0.4829D 00   0.8048D-01    0.0         0.5819E 01  -0.6586E 00  -0.6586E 00    0.0
 17       0.9690D 02   0.4398D 00   0.7330D-01    0.0         0.5506E 01  -0.9717E 00  -0.9717E 00    0.0
 29       0.9456D 02   0.3012D 00   0.5020D-01    0.0         0.5373E 01  -0.1105E 01  -0.1105E 01    0.0
 41       0.9697D 02   0.3610D 00   0.6017D-01    0.0         0.5510E 01  -0.9678E 00  -0.9678E 00    0.0
  6       0.1090D 03   0.5303D 00   0.8838D-01    0.0         0.7964E 01  -0.3648E 00  -0.3648E 00    0.0
 18       0.1015D 03   0.5274D 00   0.8790D-01    0.0         0.7415E 01  -0.9138E 00  -0.9137E 00    0.0
 30       0.9762D 02   0.3401D 00   0.5668D-01    0.0         0.7132E 01  -0.1197E 01  -0.1197E 01    0.0
 42       0.1010D 03   0.4108D 00   0.6846D-01    0.0         0.7376E 01  -0.9534E 00  -0.9533E 00    0.0
  7       0.1165D 03   0.5478D 00   0.9130D-01    0.0         0.7627E 01   0.1654E 00   0.1656E 00    0.0
 19       0.1073D 03   0.6121D 00   0.1020D 00    0.0         0.7023E 01  -0.4378E 00  -0.4376E 00    0.0
 31       0.1014D 03   0.3757D 00   0.6261D-01    0.0         0.6634E 01  -0.8275E 00  -0.8273E 00    0.0
 43       0.1057D 03   0.4530D 00   0.7551D-01    0.0         0.6920E 01  -0.5412E 00  -0.5411E 00    0.0
  8       0.1203D 03   0.5480D 00   0.9134D-01    0.0         0.8495E 01   0.4476E 00   0.4478E 00    0.0
 20       0.1105D 03   0.6497D 00   0.1083D 00    0.0         0.7800E 01  -0.2470E 00  -0.2467E 00    0.0
 32       0.1033D 03   0.3902D 00   0.6502D-01    0.0         0.7295E 01  -0.7522E 00  -0.7520E 00    0.0
 44       0.1083D 03   0.4695D 00   0.7825D-01    0.0         0.7641E 01  -0.4057E 00  -0.4055E 00    0.0
  9       0.1269D 03   0.5190D 00   0.8651D-01    0.0         0.1355E-01   0.1375E-02   0.1489E-02    0.0
 21       0.1146D 03   0.7181D 00   0.1197D 00    0.0         0.1224E-01   0.5937E-04   0.1918E-03    0.0
 33       0.1049D 03   0.3647D 00   0.6078D-01    0.0         0.1121E-01  -0.9735E-03  -0.8899E-03    0.0
 45       0.1108D 03   0.4852D 00   0.8087D-01    0.0         0.1184E-01  -0.3381E-03  -0.2434E-03    0.0
 10       0.1383D 03   0.4678D 00   0.7797D-01    0.0         0.1705E-01   0.3001E-02   0.3142E-02    0.0
 22       0.1215D 03   0.8402D 00   0.1400D 00    0.0         0.1498E-01   0.9289E-03   0.1085E-02    0.0
 34       0.1074D 03   0.3169D 00   0.5282D-01    0.0         0.1324E-01  -0.8107E-03  -0.7122E-03    0.0
 46       0.1152D 03   0.5130D 00   0.8551D-01    0.0         0.1420E-01   0.1493E-03   0.2619E-03    0.0
 11       0.1484D 03   0.4216D 00   0.7026D-01    0.0         0.1936E-01   0.4485E-02   0.4601E-02    0.0
 23       0.1275D 03   0.9497D 00   0.1583D 00    0.0         0.1664E-01   0.1761E-02   0.1894E-02    0.0
 35       0.1095D 03   0.2718D 00   0.4530D-01    0.0         0.1428E-01  -0.5935E-03  -0.5125E-03    0.0
 47       0.1189D 03   0.5382D 00   0.8970D-01    0.0         0.1551E-01   0.6336E-03   0.7290E-03    0.0

NODE        TEMP         DT           DDT          GE N RATE       W           H            F          CURE AT 280 F
 12       0.1528D 03   0.4000D 00   0.6667D-01    0.0         0.4676E-23   0.1188E-23  -0.1141E 05    0.0
 24       0.1301D 03   0.1000D 01   0.1667D 00    0.0         0.3980E-23   0.4925E-24  -0.4084E 04    0.0
 36       0.1103D 03   0.2500D 00   0.4167D-01    0.0         0.3374E-23  -0.1140E-24  -0.5604E 04    0.0
 48       0.1204D 03   0.5500D 00   0.9167D-01    0.0         0.3684E-23   0.1959E-24  -0.3829E 04    0.0
==================================================================================================
  MATERIAL DATA

    NAME  MATL     TOT CAP        TOT HEAT       AVG TEMP       TMELT          HMELT
    SAND   1     1.07359E 00    1.07665E 02    1.00285E 02    0.0            0.0
    STEL   2     2.82356E-01    3.12310E 01    1.10609E 02    0.0            0.0
    AIR    3     1.44246E-03    1.74116E-01    1.20708E 02    0.0            0.0
  ================================================================================------
```

```
TRUMP OUTPUT DATA                                                                           DATA DECK    1
 *   MISSLE PROBLEM    TWO DIMENSIONAL
=====================================================================================================================
  PRINTOUT    CYCLE   TOO FAST  TOO SLOW     KWIT     DELTMX          SMALL            TVARY        NUTS
     11        180       11        0          0    1.00000E 12    1.00000E 00    1.00000E 00      3

   TOTAL TIME     TIME STEP     HEAT FLOW    TEMP FROM FLUX   FLUX RATE     TEMP RATE
  1.18735E 03   6.31579E 00   -2.75227E 04   -2.02762E 04   -2.31800E 01   -1.70770E 01

   AVG TEMP     HEAT CAPACITY   HEAT CONTENT    GEN RATE       HEAT GEN      TEMP FROM GEN
  1.11488E 02    1.35739D 00    1.51332E 02    0.0            0.0            0.0
=====================================================================================================================

 NODE       TEMP          DT            DDT         GE N RATE       W            H            F          CURE AT 280 F
   1     0.9964D 02   0.4749D 00   0.7518D-01    0.0          0.3235E-05  -0.4663E-06  -0.9157E-03   0.0
  13     0.9964D 02   0.4749D 00   0.7518D-01    0.0          0.3235E-05  -0.4663E-06  -0.9157E-03   0.0
  25     0.9964D 02   0.4748D 00   0.7518D-01    0.0          0.3235E-05  -0.4664E-06  -0.9157E-03   0.0
  37     0.9964D 02   0.4748D 00   0.7518D-01    0.0          0.3235E-05  -0.4663E-06  -0.9157E-03   0.0
   2     0.9974D 02   0.4104D 00   0.6497D-01    0.0          0.8097E 00  -0.1158E 00  -0.1158E 00   0.0
  14     0.9890D 02   0.4133D 00   0.6544D-01    0.0          0.8028E 00  -0.1226E 00  -0.1226E 00   0.0
  26     0.9806D 02   0.3899D 00   0.6174D-01    0.0          0.7960E 00  -0.1294E 00  -0.1294E 00   0.0
  38     0.9871D 02   0.3942D 00   0.6242D-01    0.0          0.8013E 00  -0.1241E 00  -0.1241E 00   0.0
   3     0.1025D 03   0.4277D 00   0.6772D-01    0.0          0.2496E 01  -0.2803E 00  -0.2803E 00   0.0
  15     0.1001D 03   0.4448D 00   0.7042D-01    0.0          0.2439E 01  -0.3373E 00  -0.3373E 00   0.0
  27     0.9803D 02   0.3787D 00   0.5997D-01    0.0          0.2387E 01  -0.3890E 00  -0.3890E 00   0.0
  39     0.9961D 02   0.3936D 00   0.6232D-01    0.0          0.2426E 01  -0.3504E 00  -0.3504E 00   0.0
   4     0.1065D 03   0.4395D 00   0.6958D-01    0.0          0.4323E 01  -0.3038E 00  -0.3038E 00   0.0
  16     0.1028D 03   0.4877D 00   0.7722D-01    0.0          0.4172E 01  -0.4555E 00  -0.4555E 00   0.0
  28     0.9924D 02   0.3809D 00   0.6030D-01    0.0          0.4028E 01  -0.5990E 00  -0.5990E 00   0.0
  40     0.1017D 03   0.4022D 00   0.6368D-01    0.0          0.4127E 01  -0.4999E 00  -0.4999E 00   0.0
   5     0.1119D 03   0.4342D 00   0.6875D-01    0.0          0.6357E 01  -0.1206E 00  -0.1206E 00   0.0
  17     0.1070D 03   0.5399D 00   0.8548D-01    0.0          0.6080E 01  -0.3985E 00  -0.3985E 00   0.0
  29     0.1017D 03   0.3949D 00   0.6252D-01    0.0          0.5777E 01  -0.7012E 00  -0.7012E 00   0.0
  41     0.1050D 03   0.4146D 00   0.6565D-01    0.0          0.5965E 01  -0.5132E 00  -0.5132E 00   0.0
   6     0.1185D 03   0.4009D 00   0.6348D-01    0.0          0.8660E 01   0.3311E 00   0.3311E 00   0.0
  18     0.1130D 03   0.5974D 00   0.9459D-01    0.0          0.8258E 01  -0.7117E-01  -0.7111E-01   0.0
  30     0.1053D 03   0.4180D 00   0.6618D-01    0.0          0.7695E 01  -0.6338E 00  -0.6337E 00   0.0
  42     0.1095D 03   0.4251D 00   0.6731D-01    0.0          0.8002E 01  -0.3268E 00  -0.3268E 00   0.0
   7     0.1253D 03   0.3434D 00   0.5436D-01    0.0          0.8202E 01   0.7409E 00   0.7409E 00   0.0
  19     0.1201D 03   0.6488D 00   0.1027D 00    0.0          0.7863E 01   0.4020E 00   0.4022E 00   0.0
  31     0.1097D 03   0.4428D 00   0.7011D-01    0.0          0.7180E 01  -0.2812E 00  -0.2810E 00   0.0
  43     0.1147D 03   0.4286D 00   0.6785D-01    0.0          0.7505E 01   0.4382E-01   0.4392E-01   0.0
   8     0.1285D 03   0.3111D 00   0.4925D-01    0.0          0.9068E 01   0.1021E 01   0.1021E 01   0.0
  20     0.1239D 03   0.6710D 00   0.1062D 00    0.0          0.8743E 01   0.6959E 00   0.6962E 00   0.0
  32     0.1120D 03   0.4536D 00   0.7183D-01    0.0          0.7905E 01  -0.1424E 00  -0.1422E 00   0.0
  44     0.1172D 03   0.4279D 00   0.6774D-01    0.0          0.8277E 01   0.2294E 00   0.2296E 00   0.0
   9     0.1331D 03   0.2195D 00   0.3476D-01    0.0          0.1422E-01   0.2041E-02   0.2106E-02   0.0
  21     0.1292D 03   0.7331D 00   0.1161D 00    0.0          0.1380E-01   0.1620E-02   0.1753E-02   0.0
  33     0.1132D 03   0.4383D 00   0.6940D-01    0.0          0.1210E-01  -0.8174E-04   0.1249E-04   0.0
  45     0.1199D 03   0.4354D 00   0.6894D-01    0.0          0.1281E-01   0.6344E-03   0.7203E-03   0.0
  10     0.1412D 03   0.5590D-01   0.8851D-02    0.0          0.1741E-01   0.3356E-02   0.3439E-02   0.0
  22     0.1384D 03   0.8467D 00   0.1341D 00    0.0          0.1706E-01   0.3008E-02   0.3166E-02   0.0
  34     0.1152D 03   0.4095D 00   0.6483D-01    0.0          0.1420E-01   0.1494E-03   0.2604E-03   0.0
  46     0.1245D 03   0.4502D 00   0.7128D-01    0.0          0.1535E-01   0.1297E-02   0.1399E-02   0.0
  11     0.1482D 03  -0.9064D-01  -0.1435D-01    0.0          0.1934E-01   0.4467E-02   0.4531E-02   0.0
  23     0.1464D 03   0.9510D 00   0.1506D 00    0.0          0.1911E-01   0.4232E-02   0.4367E-02   0.0
  35     0.1167D 03   0.3819D 00   0.6046D-01    0.0          0.1523E-01   0.3527E-03   0.4447E-03   0.0
  47     0.1284D 03   0.4655D 00   0.7371D-01    0.0          0.1675E-01   0.1877E-02   0.1964E-02   0.0

 NODE       TEMP          DT            DDT         GE N RATE       W            H            F          CURE AT 280 F
  12     0.1513D 03  -0.1579D 00  -0.2500D-01    0.0          0.4630E-23   0.1142E-23  -0.1348E 05   0.0
  24     0.1500D 03   0.1000D 01   0.1583D 00    0.0          0.4589E-23   0.1101E-23  -0.4457E 04   0.0
  36     0.1173D 03   0.3684D 00   0.5833D-01    0.0          0.3588E-23   0.9982E-25  -0.5295E 04   0.0
  48     0.1301D 03   0.4737D 00   0.7500D-01    0.0          0.3979E-23   0.4911E-24  -0.4292E 04   0.0
=====================================================================================================================
  MATERIAL DATA

   NAME   MATL     TOT CAP        TOT HEAT       AVG TEM        TMELT         HMELT
   SAND    1     1.07359E 00    1.17152E 02    1.09122E 02    0.0           0.0
   STEL    2     2.82356E-01    3.39925E 01    1.20389E 02    0.0           0.0
   AIR     3     1.44246E-03    1.87391E-01    1.29911E 02    0.0           0.0
=====================================================================================
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```
TRUMP OUTPUT DATA                                                                                   DATA DECK    1

  *   MISSLE PROBLEM    TWO DIMENSIONAL
=====================================================================================================================

   PRINTOUT    CYCLE   TOO FAST  TOO SLOW     KWIT      DELTMX            SMALL             TVARY          NUTS
      12        200       11         0          0     1.00000E 12     1.00000E 00      1.00000E 00        4

    TOTAL TIME      TIME STEP      HEAT FLOW    TEMP FROM FLUX   FLUX RATE       TEMP RATE
   1.30776E 03    6.00006E 00    -2.75009E 04   -2.02602E 04   -2.10289E 01    -1.54922E 01

    AVG TEMP      HEAT CAPACITY   HEAT CONTENT    GEN RATE          HEAT GEN        TEMP FROM GEN
   1.17887E 02     1.357390 00    1.60018E 02    0.0               0.0              0.0
=====================================================================================================================

  NODE       TEMP          DT           DDT          GE N RATE        W            H             F          CURE AT 280 F
     1    0.1059D 03   0.3470D 00   0.5784D-01   0.0             0.3440E-05  -0.2619E-06  -0.9403E-03   0.0
    13    0.1059D 03   0.3471D 00   0.5784D-01   0.0             0.3440E-05  -0.2619E-06  -0.9403E-03   0.0
    25    0.1059D 03   0.3471D 00   0.5784D-01   0.0             0.3440E-05  -0.2620E-06  -0.9403E-03   0.0
    37    0.1059D 03   0.3470D 00   0.5784D-01   0.0             0.3440E-05  -0.2620E-06  -0.9403E-03   0.0
     2    0.1077D 03   0.3874D 00   0.6457D-01   0.0             0.8744E 00  -0.5099E-01  -0.5098E-01   0.0
    14    0.1071D 03   0.4064D 00   0.6774D-01   0.0             0.8696E 00  -0.5579E-01  -0.5579E-01   0.0
    26    0.1059D 03   0.3972D 00   0.6619D-01   0.0             0.8600E 00  -0.6540E-01  -0.6540E-01   0.0
    38    0.1065D 03   0.3883D 00   0.6472D-01   0.0             0.8649E 00  -0.6053E-01  -0.6053E-01   0.0
     3    0.1104D 03   0.3607D 00   0.6012D-01   0.0             0.2688E 01  -0.8810E-01  -0.8809E-01   0.0
    15    0.1089D 03   0.4201D 00   0.7001D-01   0.0             0.2652E 01  -0.1242E 00  -0.1242E 00   0.0
    27    0.1058D 03   0.3914D 00   0.6523D-01   0.0             0.2576E 01  -0.2005E 00  -0.2005E 00   0.0
    39    0.1073D 03   0.3747D 00   0.6244D-01   0.0             0.2613E 01  -0.1628E 00  -0.1628E 00   0.0
     4    0.1140D 03   0.3090D 00   0.5149D-01   0.0             0.4629E 01   0.1842E-02   0.1845E-02   0.0
    16    0.1120D 03   0.4151D 00   0.6919D-01   0.0             0.4546E 01  -0.8069E-01  -0.8068E-01   0.0
    28    0.1069D 03   0.3789D 00   0.6314D-01   0.0             0.4340E 01  -0.2876E 00  -0.2875E 00   0.0
    40    0.1093D 03   0.3525D 00   0.5874D-01   0.0             0.4436E 01  -0.1915E 00  -0.1915E 00   0.0
     5    0.1185D 03   0.2169D 00   0.3615D-01   0.0             0.6732E 01   0.2544E 00   0.2543E 00   0.0
    17    0.1164D 03   0.3757D 00   0.6262D-01   0.0             0.6617E 01   0.1387E 00   0.1387E 00   0.0
    29    0.1093D 03   0.3557D 00   0.5929D-01   0.0             0.6210E 01  -0.2679E 00  -0.2679E 00   0.0
    41    0.1123D 03   0.3125D 00   0.5209D-01   0.0             0.6383E 01  -0.9510E-01  -0.9509E-01   0.0
     6    0.1232D 03   0.7017D-01   0.1170D-01   0.0             0.9002E 01   0.6734E 00   0.6733E 00   0.0
    18    0.1220D 03   0.2842D 00   0.4737D-01   0.0             0.8912E 01   0.5829E 00   0.5829E 00   0.0
    30    0.1127D 03   0.3143D 00   0.5238D-01   0.0             0.8237E 01  -0.9183E-01  -0.9179E-01   0.0
    42    0.1162D 03   0.2447D 00   0.4078D-01   0.0             0.8493E 01   0.1642E 00   0.1642E 00   0.0
     7    0.1270D 03  -0.1097D 00  -0.1828D-01   0.0             0.8311E 01   0.8500E 00   0.8499E 00   0.0
    19    0.1274D 03   0.1508D 00   0.2513D-01   0.0             0.8337E 01   0.8756E 00   0.8757E 00   0.0
    31    0.1165D 03   0.2559D 00   0.4266D-01   0.0             0.7627E 01   0.1655E 00   0.1656E 00   0.0
    43    0.1201D 03   0.1556D 00   0.2593D-01   0.0             0.7864E 01   0.4024E 00   0.4025E 00   0.0
     8    0.1282D 03  -0.1997D 00  -0.3328D-01   0.0             0.9051E 01   0.1004E 01   0.1004E 01   0.0
    20    0.1297D 03   0.7951D-01   0.1325D-01   0.0             0.9154E 01   0.1107E 01   0.1108E 01   0.0
    32    0.1183D 03   0.2238D 00   0.3730D-01   0.0             0.8351E 01   0.3040E 00   0.3042E 00   0.0
    44    0.1218D 03   0.1090D 00   0.1816D-01   0.0             0.8601E 01   0.5539E 00   0.5541E 00   0.0
     9    0.1293D 03  -0.3598D 00  -0.5997D-01   0.0             0.1381E-01   0.1631E-02   0.1649E-02   0.0
    21    0.1333D 03   0.9844D-02   0.1641D-02   0.0             0.1424E-01   0.2057E-02   0.2148E-02   0.0
    33    0.1189D 03   0.2061D 00   0.3435D-01   0.0             0.1271E-01   0.5276E-03   0.6102E-03   0.0
    45    0.1236D 03   0.7355D-01   0.1226D-01   0.0             0.1320E-01   0.1022E-02   0.1086E-02   0.0
    10    0.1310D 03  -0.6420D 00  -0.1070D 00   0.0             0.1615E-01   0.2101E-02   0.2129E-02   0.0
    22    0.1395D 03  -0.1086D 00  -0.1810D-01   0.0             0.1720E-01   0.3149E-02   0.3255E-02   0.0
    34    0.1199D 03   0.1784D 00   0.2974D-01   0.0             0.1478E-01   0.7234E-03   0.8210E-03   0.0
    46    0.1265D 03   0.1513D-01   0.2522D-02   0.0             0.1559E-01   0.1541E-02   0.1619E-02   0.0
    11    0.1325D 03  -0.8893D 00  -0.1482D 00   0.0             0.1729E-01   0.2410E-02   0.2425E-02   0.0
    23    0.1450D 03  -0.2078D 00  -0.3463D-01   0.0             0.1893E-01   0.4052E-02   0.4140E-02   0.0
    35    0.1205D 03   0.1577D 00   0.2628D-01   0.0             0.1572E-01   0.8477E-03   0.9280E-03   0.0
    47    0.1290D 03  -0.3141D-01  -0.5235D-02   0.0             0.1684E-01   0.1958E-02   0.2023E-02   0.0

  NODE       TEMP          DT           DDT          GE N RATE        W            H             F          CURE AT 280 F
    12    0.1330D 03  -0.1000D 01  -0.1667D 00   0.0             0.4071E-23   0.5825E-24  -0.1339E 05   0.0
    24    0.1475D 03  -0.2500D 00  -0.4167D-01   0.0             0.4513E-23   0.1025E-23  -0.4495E 04   0.0
    36    0.1207D 03   0.1500D 00   0.2500D-01   0.0             0.3693E-23   0.2048E-24  -0.5314E 04   0.0
    48    0.1301D 03  -0.5000D-01  -0.8334D-02   0.0             0.3981E-23   0.4927E-24  -0.4305E 04   0.0
=====================================================================================================================
   MATERIAL DATA

     NAME   MATL      TOT CAP          TOT HEAT          AVG TEMP        TMELT           HMELT
     SAND     1     1.07359E 00      1.24674E 02      1.16128E 02     0.0             0.0
     STEL     2     2.82356E-01      3.51579E 01      1.24517E 02     0.0             0.0
     AIR      3     1.44246E-03      1.86460E-01      1.29265E 02     0.0             0.0
   ==================================================================================================
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```
    TRUMP OUTPUT DATA                                                                                     DATA DECK    1
    *   MISSLE PROBLEM    TWO DIMENSIONAL
=====================================================================================================================

   PRINTOUT    CYCLE    TOO FAST  TOO SLOW     KWIT      DELTMX           SMALL           TVARY         NUTS
     13         220        11         0          0    1.00000E 12     1.00000E 00    1.00000E 00      3

     TOTAL TIME      TIME STEP       HEAT FLOW     TEMP FROM FLUX    FLUX RATE       TEMP RATE
    1.36145E 03     2.71381E 00     1.10823E 04     8.16445E 03     8.14007E 00     5.99687E 00

     AVG TEMP      HEAT CAPACITY    HEAT CONTENT     GEN RATE        HEAT GEN       TEMP FROM GEN
    1.18861E 02     1.357390 00     1.61341E 02     0.0             0.0             0.0
=====================================================================================================================

 NODE        TEMP          DT            DDT         GE N RATE        W            H             F         CURE AT 280 F
   1     0.1092D 03   0.2566D 00    0.9381D-01    0.0          0.3546E-05  -0.1554E-06  -0.8399E-03    0.0
  13     0.1092D 03   0.2566D 00    0.9382D-01    0.0          0.3546E-05  -0.1554E-06  -0.8399E-03    0.0
  25     0.1092D 03   0.2566D 00    0.9382D-01    0.0          0.3546E-05  -0.1555E-06  -0.8398E-03    0.0
  37     0.1092D 03   0.2566D 00    0.9382D-01    0.0          0.3546E-05  -0.1554E-06  -0.8399E-03    0.0
   2     0.1110D 03   0.1546D 00    0.5651D-01    0.0          0.9010E 00  -0.2447E-01  -0.2447E-01    0.0
  14     0.1106D 03   0.1644D 00    0.6011D-01    0.0          0.8977E 00  -0.2777E-01  -0.2777E-01    0.0
  26     0.1094D 03   0.1653D 00    0.6044D-01    0.0          0.8878E 00  -0.3762E-01  -0.3761E-01    0.0
  38     0.1099D 03   0.1594D 00    0.5829D-01    0.0          0.8919E 00  -0.3357E-01  -0.3356E-01    0.0
   3     0.1133D 03   0.1333D 00    0.4872D-01    0.0          0.2759E 01  -0.1684E-01  -0.1683E-01    0.0
  15     0.1124D 03   0.1623D 00    0.5935D-01    0.0          0.2737E 01  -0.3921E-01  -0.3921E-01    0.0
  27     0.1091D 03   0.1633D 00    0.5971D-01    0.0          0.2658E 01  -0.1182E 00  -0.1182E 00    0.0
  39     0.1105D 03   0.1507D 00    0.5508D-01    0.0          0.2691E 01  -0.8557E-01  -0.8556E-01    0.0
   4     0.1164D 03   0.9789D-01    0.3579D-01    0.0          0.4724E 01   0.9660E-01   0.9661E-01    0.0
  16     0.1153D 03   0.1460D 00    0.5337D-01    0.0          0.4681E 01   0.5359E-01   0.5360E-01    0.0
  28     0.1101D 03   0.1528D 00    0.5585D-01    0.0          0.4471E 01  -0.1566E 00  -0.1566E 00    0.0
  40     0.1122D 03   0.1336D 00    0.4883D-01    0.0          0.4554E 01  -0.7363E-01  -0.7362E-01    0.0
   5     0.1198D 03   0.4144D-01    0.1515D-01    0.0          0.6810E 01   0.3324E 00   0.3324E 00    0.0
  17     0.1192D 03   0.1035D 00    0.3784D-01    0.0          0.6773E 01   0.2954E 00   0.2954E 00    0.0
  29     0.1122D 03   0.1285D 00    0.4698D-01    0.0          0.6376E 01  -0.1022E 00  -0.1022E 00    0.0
  41     0.1148D 03   0.1019D 00    0.3726D-01    0.0          0.6521E 01   0.4338E-01   0.4338E-01    0.0
   6     0.1231D 03  -0.4786D-01   -0.1750D-01    0.0          0.8995E 01   0.6657E 00   0.6657E 00    0.0
  18     0.1235D 03   0.1003D-01    0.3666D-02    0.0          0.9026E 01   0.6970E 00   0.6971E 00    0.0
  30     0.1150D 03   0.7526D-01    0.2751D-01    0.0          0.8405E 01   0.7594E-01   0.7598E-01    0.0
  42     0.1179D 03   0.4200D-01    0.1536D-01    0.0          0.8611E 01   0.2824E 00   0.2824E 00    0.0
   7     0.1249D 03  -0.1704D 00   -0.6228D-01    0.0          0.8176E 01   0.7143E 00   0.7143E 00    0.0
  19     0.1268D 03  -0.1516D 00   -0.5543D-01    0.0          0.8298E 01   0.8372E 00   0.8373E 00    0.0
  31     0.1177D 03  -0.2137D-01   -0.7811D-02    0.0          0.7701E 01   0.2394E 00   0.2395E 00    0.0
  43     0.1204D 03  -0.5579D-01   -0.2040D-01    0.0          0.7883E 01   0.4215E 00   0.4216E 00    0.0
   8     0.1250D 03  -0.2398D 00   -0.8768D-01    0.0          0.8820E 01   0.7733E 00   0.7732E 00    0.0
  20     0.1275D 03  -0.2517D 00   -0.9201D-01    0.0          0.8998E 01   0.9510E 00   0.9511E 00    0.0
  32     0.1185D 03  -0.8422D-01   -0.3079D-01    0.0          0.8364E 01   0.3172E 00   0.3173E 00    0.0
  44     0.1212D 03  -0.1163D 00   -0.4251D-01    0.0          0.8554E 01   0.5066E 00   0.5067E 00    0.0
   9     0.1240D 03  -0.3411D 00   -0.1247D 00    0.0          0.1325E-01   0.1068E-02   0.1047E-02    0.0
  21     0.1283D 03  -0.4048D 00   -0.1480D 00    0.0          0.1371E-01   0.1531E-02   0.1568E-02    0.0
  33     0.1179D 03  -0.1540D 00   -0.5631D-01    0.0          0.1259E-01   0.4119E-03   0.4653E-03    0.0
  45     0.1215D 03  -0.1921D 00   -0.7024D-01    0.0          0.1298E-01   0.8035E-03   0.8394E-03    0.0
  10     0.1223D 03  -0.5152D 00   -0.1883D 00    0.0          0.1507E-01   0.1021E-02   0.1005E-02    0.0
  22     0.1299D 03  -0.6701D 00   -0.2450D 00    0.0          0.1601E-01   0.1958E-02   0.2002E-02    0.0
  34     0.1166D 03  -0.2714D 00   -0.9922D-01    0.0          0.1438E-01   0.3219E-03   0.3835E-03    0.0
  46     0.1221D 03  -0.3214D 00   -0.1175D 00    0.0          0.1505E-01   0.9971E-03   0.1042E-02    0.0
  11     0.1207D 03  -0.6619D 00   -0.2420D 00    0.0          0.1575E-01   0.8751E-03   0.8542E-03    0.0
  23     0.1312D 03  -0.8972D 00   -0.3280D 00    0.0          0.1712E-01   0.2247E-02   0.2285E-02    0.0
  35     0.1154D 03  -0.3677D 00   -0.1344D 00    0.0          0.1506E-01   0.1816E-03   0.2329E-03    0.0
  47     0.1226D 03  -0.4296D 00   -0.1570D 00    0.0          0.1599E-01   0.1116E-02   0.1154E-02    0.0

 NODE        TEMP          DT            DDT         GE N RATE        W            H             F         CURE AT 280 F
  12     0.1199D 03  -0.7210D 00   -0.2636D 00    0.0          0.3670E-23   0.1820E-24  -0.1674E 04    0.0
  24     0.1318D 03  -0.9916D 00   -0.3625D 00    0.0          0.4033E-23   0.5447E-24   0.1004E 05    0.0
  36     0.1148D 03  -0.4057D 00   -0.1483D 00    0.0          0.3512E-23   0.2397E-25   0.1783E 03    0.0
  48     0.1227D 03  -0.4733D 00   -0.1730D 00    0.0          0.3756E-23   0.2676E-24   0.2535E 04    0.0
=====================================================================================================================
    MATERIAL DATA

     NAME  MATL      TOT CAP        TOT HEAT        AVG TEMP       TMELT          HMELT
     SAND    1     1.07359E 00     1.26427E 02     1.17762E 02     0.0            0.0
     STEL    2     2.82356E-01     3.47364E 01     1.23024E 02     0.0            0.0
     AIR     3     1.44246E-03     1.76973E-01     1.22689E 02     0.0            0.0
=====================================================================================================================
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TRUMP OUTPUT DATA                                                                         DATA DECK    1

 *   MISSLE PROBLEM    TWO DIMENSIONAL
==================================================================================================================

  PRINTOUT     CYCLE    TOO FAST   TOO SLOW      KWIT      DELTMX           SMALL            TVARY         NUTS
     14         240        11          0           0     1.00000E 12      1.00000E 00     1.00000E 00        3

   TOTAL TIME      TIME STEP       HEAT FLOW      TEMP FROM FLUX    FLUX RATE       TEMP RATE
  1.41596E 03     2.72729E 00     1.04046E 04      7.66514E 03     7.34804E 00     5.41337E 00

    AVG TEMP      HEAT CAPACITY    HEAT CONTENT     GEN RATE         HEAT GEN        TEMP FROM GEN
  1.17767E 02     1.35739D 00     1.59855E 02     0.0              0.0              0.0
==================================================================================================================

NODE        TEMP          DT            DDT          GE N RATE        W            H            F          CURE AT 280 F
  1      0.1145D 03    0.1520D 00    0.5575D-01    0.0            0.3717E-05    0.1478E-07  -0.8721E-03    0.0
 13      0.1145D 03    0.1521D 00    0.5575D-01    0.0            0.3717E-05    0.1476E-07  -0.8721E-03    0.0
 25      0.1145D 03    0.1521D 00    0.5576D-01    0.0            0.3716E-05    0.1467E-07  -0.8721E-03    0.0
 37      0.1145D 03    0.1521D 00    0.5575D-01    0.0            0.3716E-05    0.1470E-07  -0.8721E-03    0.0
  2      0.1138D 03    0.1198D 00    0.4394D-01    0.0            0.9234E 00   -0.2001E-02  -0.1997E-02    0.0
 14      0.1135D 03    0.1281D 00    0.4696D-01    0.0            0.9216E 00   -0.3782E-02  -0.3777E-02    0.0
 26      0.1124D 03    0.1345D 00    0.4932D-01    0.0            0.9124E 00   -0.1301E-01  -0.1301E-01    0.0
 38      0.1128D 03    0.1284D 00    0.4709D-01    0.0            0.9155E 00   -0.9971E-02  -0.9967E-02    0.0
  3      0.1156D 03    0.8969D-01    0.3288D-01    0.0            0.2814E 01    0.3782E-01   0.3782E-01    0.0
 15      0.1152D 03    0.1119D 00    0.4102D-01    0.0            0.2805E 01    0.2828E-01   0.2829E-01    0.0
 27      0.1121D 03    0.1290D 00    0.4728D-01    0.0            0.2730E 01   -0.4617E-01  -0.4616E-01    0.0
 39      0.1132D 03    0.1151D 00    0.4218D-01    0.0            0.2756E 01   -0.2025E-01  -0.2024E-01    0.0
  4      0.1178D 03    0.3995D-01    0.1465D-01    0.0            0.4780E 01    0.1527E 00   0.1527E 00    0.0
 16      0.1175D 03    0.7027D-01    0.2576D-01    0.0            0.4769E 01    0.1421E 00   0.1421E 00    0.0
 28      0.1127D 03    0.1048D 00    0.3843D-01    0.0            0.4576E 01   -0.5082E-01  -0.5081E-01    0.0
 40      0.1144D 03    0.8503D-01    0.3117D-01    0.0            0.4643E 01    0.1583E-01   0.1584E-01    0.0
  5      0.1199D 03   -0.3562D-01   -0.1306D-01    0.0            0.6812E 01    0.3342E 00   0.3342E 00    0.0
 17      0.1201D 03   -0.8963D-02   -0.3286D-02    0.0            0.6825E 01    0.3467E 00   0.3467E 00    0.0
 29      0.1140D 03    0.5584D-01    0.2047D-01    0.0            0.6480E 01    0.2357E-02   0.2377E-02    0.0
 41      0.1161D 03    0.3206D-01    0.1176D-01    0.0            0.6597E 01    0.1188E 00   0.1188E 00    0.0
  6      0.1211D 03   -0.1427D 00   -0.5233D-01    0.0            0.8849E 01    0.5199E 00   0.5199E 00    0.0
 18      0.1221D 03   -0.1376D 00   -0.5046D-01    0.0            0.8920E 01    0.5914E 00   0.5914E 00    0.0
 30      0.1154D 03   -0.2634D-01   -0.9658D-02    0.0            0.8434E 01    0.1053E 00   0.1054E 00    0.0
 42      0.1177D 03   -0.5116D-01   -0.1876D-01    0.0            0.8598E 01    0.2696E 00   0.2696E 00    0.0
  7      0.1204D 03   -0.2644D 00   -0.9694D-01    0.0            0.7882E 01    0.4203E 00   0.4202E 00    0.0
 19      0.1221D 03   -0.2950D 00   -0.1082D 00    0.0            0.7989E 01    0.5276E 00   0.5277E 00    0.0
 31      0.1160D 03   -0.1310D 00   -0.4803D-01    0.0            0.7590E 01    0.1289E 00   0.1290E 00    0.0
 43      0.1182D 03   -0.1531D 00   -0.5613D-01    0.0            0.7737E 01    0.2753E 00   0.2753E 00    0.0
  8      0.1192D 03   -0.3230D 00   -0.1184D 00    0.0            0.8413E 01    0.3657E 00   0.3657E 00    0.0
 20      0.1210D 03   -0.3724D 00   -0.1365D 00    0.0            0.8540E 01    0.4929E 00   0.4930E 00    0.0
 32      0.1156D 03   -0.1844D 00   -0.6760D-01    0.0            0.8163E 01    0.1158E 00   0.1159E 00    0.0
 44      0.1178D 03   -0.2042D 00   -0.7487D-01    0.0            0.8317E 01    0.2701E 00   0.2702E 00    0.0
  9      0.1164D 03   -0.4068D 00   -0.1492D 00    0.0            0.1244E-01    0.2574E-03   0.2306E-03    0.0
 21      0.1191D 03   -0.4999D 00   -0.1833D 00    0.0            0.1272E-01    0.5446E-03   0.5727E-03    0.0
 33      0.1139D 03   -0.2333D 00   -0.8555D-01    0.0            0.1216E-01   -0.1583E-04   0.3141E-04    0.0
 45      0.1169D 03   -0.2618D 00   -0.9597D-01    0.0            0.1249E-01    0.3065E-03   0.3369E-03    0.0
 10      0.1116D 03   -0.5513D 00   -0.2021D 00    0.0            0.1375E-01   -0.2999E-03  -0.3233E-03    0.0
 22      0.1159D 03   -0.7223D 00   -0.2648D 00    0.0            0.1428E-01    0.2292E-03   0.2637E-03    0.0
 34      0.1107D 03   -0.3151D 00   -0.1155D 00    0.0            0.1364E-01   -0.4096E-03  -0.3556E-03    0.0
 46      0.1152D 03   -0.3597D 00   -0.1319D 00    0.0            0.1420E-01    0.1501E-03   0.1883E-03    0.0
 11      0.1073D 03   -0.6740D 00   -0.2471D 00    0.0            0.1401E-01   -0.8712E-03  -0.8979E-03    0.0
 23      0.1131D 03   -0.9147D 00   -0.3354D 00    0.0            0.1475E-01   -0.1222E-03  -0.9285E-04    0.0
 35      0.1079D 03   -0.3816D 00   -0.1399D 00    0.0            0.1408E-01   -0.7995E-03  -0.7542E-03    0.0
 47      0.1138D 03   -0.442[illegible] 00   -0.1621D 00    0.0            0.1485E-01   -0.2399E-04   0.8336E-05    0.0

NODE        TEMP          DT            DDT          GE N RATE        W            H            F          CURE AT 280 F
 12      0.1054D 03   -0.7272D 00   -0.2666D 00    0.0            0.3225E-23   -0.2628E-24  -0.1863E 04    0.0
 24      0.1118D 03   -0.9999D 00   -0.3666D 00    0.0            0.3421E-23   -0.6690E-25   0.9778E 04    0.0
 36      0.1066D 03   -0.4091D 00   -0.1500D 00    0.0            0.3262E-23   -0.2262E-24   0.7301E 02    0.0
 48      0.1132D 03   -0.4772D 00   -0.1750D 00    0.0            0.3464E-23   -0.2427E-25   0.2412E 04    0.0
==================================================================================================================
  MATERIAL DATA

   NAME   MATL      TOT CAP        TOT HEAT        AVG TEMP        TMELT          HMELT
   SAND     1     1.07359E 00    1.26259E 02    1.17605E 02     0.0            0.0
   STEL     2     2.82356E-01    3.34328E 01    1.18407E 02     0.0            0.0
   AIR      3     1.44246E-03    1.63385E-01    1.13269E 02     0.0            0.0
   ==========================================================---------------------------------------
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TRUMP OUTPUT DATA                                                                              DATA DECK    1
 *  MISSLE PROBLEM    TWO DIMENSIONAL
=============================================================================================================
  PRINTOUT     CYCLE   TOO FAST  TOO SLOW     KWIT     DELTMX           SMALL          TVARY        NUTS
     15         249       11         0          1    1.00000E 12    1.00000E 00    1.00000E 00      2

   TOTAL TIME     TIME STEP       HEAT FLOW     TEMP FROM FLUX   FLUX RATE       TEMP RATE
  1.44000E 03    2.21753E 00     1.04904E 04      7.72841E 03   7.28502E 00     5.36695E 00

    AVG TEMP     HEAT CAPACITY    HEAT CONTENT     GEN RATE         HEAT GEN       TEMP FROM GEN
  1.16772E 02     1.35739D 00     1.58504E 02     0.0              0.0             0.0
=============================================================================================================

 NODE        TEMP         DT             DDT         GE N RATE         W            H             F          CURE AT 280 F
   1     0.1150D 03  -0.1338D-02   -0.4574D-27    0.0           0.3734E-05   0.3256E-07  -0.9208E-03    0.0
  13     0.1150D 03  -0.1325D-02   -0.4531D-27    0.0           0.3734E-05   0.3254E-07  -0.9208E-03    0.0
  25     0.1150D 03  -0.1307D-02   -0.4469D-27    0.0           0.3734E-05   0.3246E-07  -0.9208E-03    0.0
  37     0.1150D 03  -0.1319D-02   -0.4508D-27    0.0           0.3734E-05   0.3248E-07  -0.9208E-03    0.0
   2     0.1147D 03   0.7875D-01    0.2692D-01    0.0           0.9311E 00   0.5690E-02   0.5693E-02    0.0
  14     0.1145D 03   0.8413D-01    0.2876D-01    0.0           0.9299E 00   0.4436E-02   0.4440E-02    0.0
  26     0.1135D 03   0.9132D-01    0.3122D-01    0.0           0.9212E 00  -0.4240E-02  -0.4236E-02    0.0
  38     0.1138D 03   0.8684D-01    0.2968D-01    0.0           0.9238E 00  -0.1611E-02  -0.1608E-02    0.0
   3     0.1162D 03   0.5225D-01    0.1786D-01    0.0           0.2830E 01   0.5411E-01   0.5412E-01    0.0
  15     0.1160D 03   0.6596D-01    0.2255D-01    0.0           0.2825E 01   0.4871E-01   0.4872E-01    0.0
  27     0.1131D 03   0.8552D-01    0.2924D-01    0.0           0.2755E 01  -0.2123E-01  -0.2123E-01    0.0
  39     0.1141D 03   0.7497D-01    0.2563D-01    0.0           0.2778E 01   0.1802E-02   0.1806E-02    0.0
   4     0.1180D 03   0.8271D-02    0.2827D-02    0.0           0.4788E 01   0.1611E 00   0.1611E 00    0.0
  16     0.1179D 03   0.2504D-01    0.8559D-02    0.0           0.4787E 01   0.1594E 00   0.1594E 00    0.0
  28     0.1135D 03   0.6199D-01    0.2119D-01    0.0           0.4608E 01  -0.1889E-01  -0.1889E-01    0.0
  40     0.1150D 03   0.4713D-01    0.1611D-01    0.0           0.4668E 01   0.4096E-01   0.4096E-01    0.0
   5     0.1194D 03  -0.5635D-01   -0.1926D-01    0.0           0.6785E 01   0.3070E 00   0.3070E 00    0.0
  17     0.1198D 03  -0.4568D-01   -0.1562D-01    0.0           0.6807E 01   0.3290E 00   0.3290E 00    0.0
  29     0.1144D 03   0.1746D-01    0.5970D-02    0.0           0.6499E 01   0.2079E-01   0.2081E-01    0.0
  41     0.1162D 03   0.1715D-03    0.5862D-04    0.0           0.6604E 01   0.1260E 00   0.1260E 00    0.0
   6     0.1197D 03  -0.1435D 00   -0.4906D-01    0.0           0.8745E 01   0.4157E 00   0.4157E 00    0.0
  18     0.1206D 03  -0.1508D 00   -0.5154D-01    0.0           0.8814E 01   0.4853E 00   0.4853E 00    0.0
  30     0.1150D 03  -0.5152D-01   -0.1761D-01    0.0           0.8404E 01   0.7496E-01   0.7499E-01    0.0
  42     0.1171D 03  -0.6891D-01   -0.2356D-01    0.0           0.8553E 01   0.2244E 00   0.2245E 00    0.0
   7     0.1180D 03  -0.2373D 00   -0.8112D-01    0.0           0.7720E 01   0.2588E 00   0.2587E 00    0.0
  19     0.1193D 03  -0.2698D 00   -0.9222D-01    0.0           0.7806E 01   0.3452E 00   0.3453E 00    0.0
  31     0.1147D 03  -0.1329D 00   -0.4545D-01    0.0           0.7504E 01   0.4266E-01   0.4277E-01    0.0
  43     0.1167D 03  -0.1481D 00   -0.5062D-01    0.0           0.7639E 01   0.1774E 00   0.1775E 00    0.0
   8     0.1162D 03  -0.2809D 00   -0.9602D-01    0.0           0.8204E 01   0.1568E 00   0.1567E 00    0.0
  20     0.1176D 03  -0.3257D 00   -0.1114D 00    0.0           0.8298E 01   0.2510E 00   0.2511E 00    0.0
  32     0.1139D 03  -0.1726D 00   -0.5901D-01    0.0           0.8038E 01  -0.8874E-02  -0.8729E-02    0.0
  44     0.1159D 03  -0.1862D 00   -0.6366D-01    0.0           0.8181E 01   0.1342E 00   0.1343E 00    0.0
   9     0.1127D 03  -0.3452D 00   -0.1180D 00    0.0           0.1204E-01  -0.1353E-03  -0.1635E-03    0.0
  21     0.1146D 03  -0.4246D 00   -0.1452D 00    0.0           0.1224E-01   0.6163E-04   0.8797E-04    0.0
  33     0.1117D 03  -0.2077D 00   -0.7098D-01    0.0           0.1193E-01  -0.2474E-03  -0.2019E-03    0.0
  45     0.1145D 03  -0.2288D 00   -0.7821D-01    0.0           0.1223E-01   0.4945E-04   0.7832E-04    0.0
  10     0.1067D 03  -0.4562D 00   -0.1560D 00    0.0           0.1315E-01  -0.9050E-03  -0.9300E-03    0.0
  22     0.1094D 03  -0.5972D 00   -0.2042D 00    0.0           0.1349E-01  -0.5633E-03  -0.5307E-03    0.0
  34     0.1078D 03  -0.2660D 00   -0.9094D-01    0.0           0.1329E-01  -0.7594E-03  -0.7074E-03    0.0
  46     0.1120D 03  -0.3012D 00   -0.1030D 00    0.0           0.1381E-01  -0.2474E-03  -0.2110E-03    0.0
  11     0.1014D 03  -0.5505D 00   -0.1882D 00    0.0           0.1323E-01  -0.1648E-02  -0.1676E-02    0.0
  23     0.1050D 03  -0.7468D 00   -0.2553D 00    0.0           0.1370E-01  -0.1177E-02  -0.1149E-02    0.0
  35     0.1045D 03  -0.3133D 00   -0.1071D 00    0.0           0.1364E-01  -0.1241E-02  -0.1197E-02    0.0
  47     0.1099D 03  -0.3620D 00   -0.1238D 00    0.0           0.1434E-01  -0.5345E-03  -0.5035E-03    0.0

 NODE        TEMP         DT             DDT         GE N RATE         W            H             F          CURE AT 280 F
  12     0.9900D 02  -0.5913D 00   -0.2021D 00    0.0           0.3029E-23  -0.4589E-24  -0.1839E 04    0.0
  24     0.1030D 03  -0.8131D 00   -0.2779D 00    0.0           0.3151E-23  -0.3365E-24   0.9811E 04    0.0
  36     0.1030D 03  -0.3326D 00   -0.1137D 00    0.0           0.3151E-23  -0.3365E-24   0.8650E 02    0.0
  48     0.1090D 03  -0.3881D 00   -0.1327D 00    0.0           0.3335E-23  -0.1530E-24   0.2428E 04    0.0
=============================================================================================================
   MATERIAL DATA

     NAME   MATL      TOT CAP         TOT HEAT        AVG TEMP       TMELT         HMELT
     SAND     1     1.07359E 00     1.25626E 02     1.17015E 02    0.0           0.0
     STEL     2     2.82356E-01     3.27215E 01     1.15887E 02    0.0           0.0
     AIR      3     1.44246E-03     1.57092E-01     1.08906E 02    0.0           0.0
=============================================================================================================
```

APPENDIX D

Experimental Data

The data presented in this appendix were obtained from the thermocouples on the rocket motor storage container system located at China Lake, California. The thermocouple output was read out on a Honeywell Electronik 25, 24 channel recorder which had been calibrated at 50, 100 and 150°F. The data was taken on two consecutive, typical summer days (August 1 and 2, 1972) at China Lake. Each thermocouple was read once every 24 minutes. The first set of data presents the storage container temperature at four locations plus three different ways of averaging this data. It also presents the ambient temperature and the approximate time of day. The second set of data presents the surface temperature of the rocket motor and three ways to average this data. It also presents the temperature at the center of the rocket motor and the approximate time of day. Figure 32 shows the location of the thermocouples used to collect this temperature data.

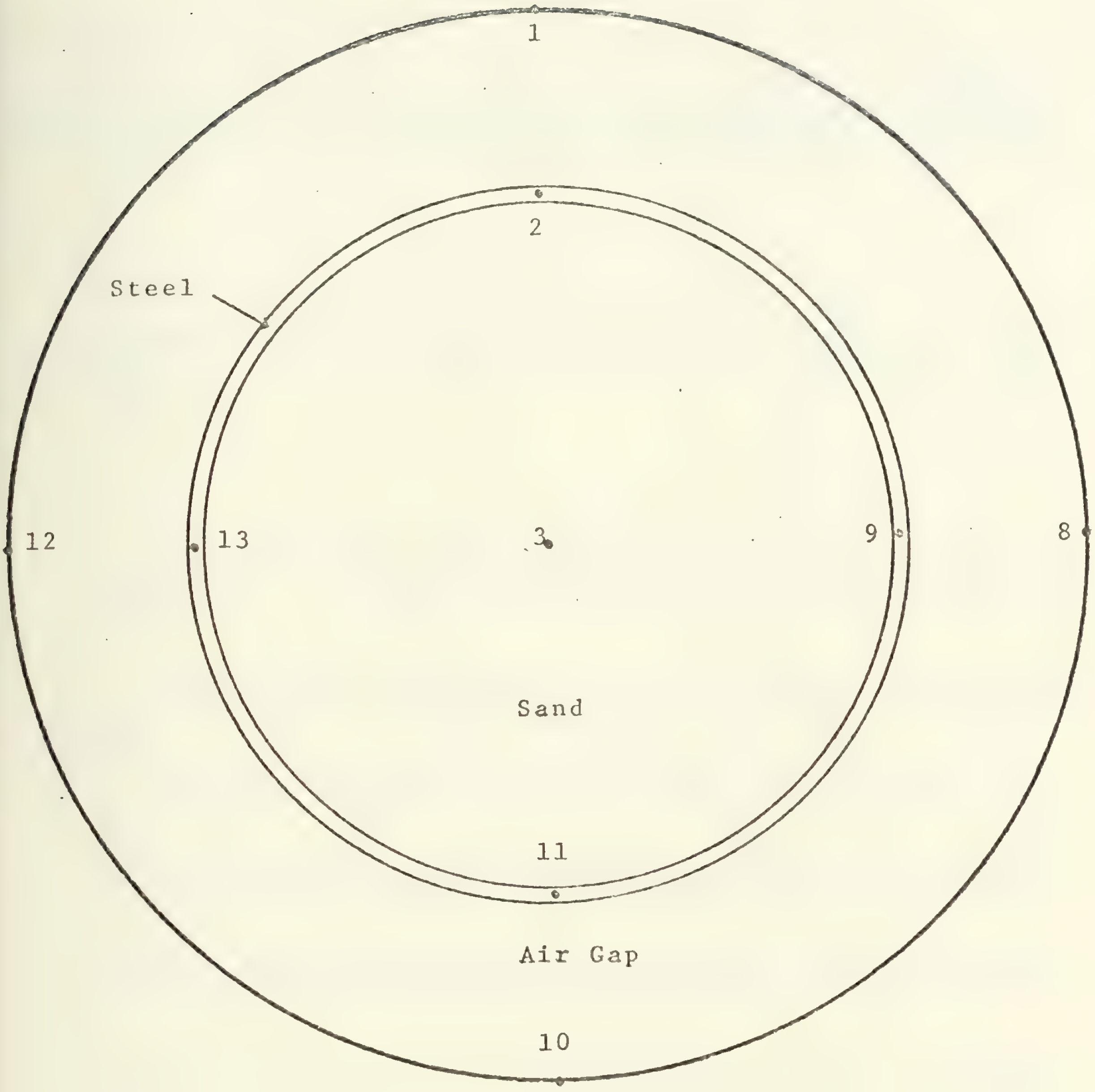

Figure 32: Thermocouple Locations for Experimental Data.

Series 1

Time (Approximate) Aug. 1, 1972	Ambient (°F)	#1 (°F)	#8 (°F)	#10 (°F)	#12 (°F)	Avg. #1 & #10 (°F)	Avg. #8 & #12 (°F)	Avg. all 4 "Bulk"
0536	76	69	72	79	80	74	76	75
0600	77	68	72	79	80	73.5	76	74.75
0624	80	73	75	81	82	77	78.5	77.75
0648	80	81	79	87	85	84	82	83
0712	83	90	82	90	89	90	85.5	87.75
0736	85	98	87	93	92	95.5	89.5	92.5
0800	87	105	90	94	94	99.5	92	95.75
	89	110	93	96	97	103	95	99
	91	116	96	98	99	107	97.5	102.25
	92	121	100	101	102	111	101	106
	94	129	103	102	105	115.5	104	109.75
1000	96	133	107	105	108	119	107.5	113.25
	97	139	110	107	110	123	110	116.5
	100	143	113	107	112	125	112.5	118.75
	101	147	117	109	115	128	116	122
	103	150	119	109	116	129.5	117.5	123.5
1200	104	153	124	110	119	131.5	121.5	126.5
	106	156	128	112	122	134	125	129.5
	106	157	131	113	124	135	127.5	131.25
	106	154	133	114	125	134	129	131.5
	107	157	138	115	127	136	132.5	134.25
1400	108	154	143	117	129	135.5	136	135.75
	109	153	142	118	129	135.5	135.5	135.5
	110	148	142	119	129	133.5	135.5	134.5
	110	143	141	118	128	130.5	134.5	132.5
	109	142	143	119	128	130.5	135.5	133
1600	107	137	143	119	128	128	135.5	131.75
	108	134	139	117	127	125.5	133	129.25
	108	130	139	117	127	123.5	133	128.25
	106	126	138	116	126	121	132	126.5
	104	123	136	115	125	119	130.5	124.75

Time (Approximate) Aug. 1, 1972	Ambient (°F)	#1 (°F)	#8 (°F)	#10 (°F)	#12 (°F)	Avg. #1 & #10 (°F)	Avg. #8 & #12 (°F)	Avg. all 4 "Bulk
1800	103	118	131	113	123	115.5	127	121.25
	101	113	127	111	120	112	123.5	117.75
	99	107	121	108	117	107.5	119	113.25
	96	101	106	103	111	102	108.5	105.25
	95	91	93	98	104	94.5	98.5	96.5
2000	93	88	91	95	101	91.5	96	93.75
	91	86	89	94	99	90	94	92
	90	85	88	92	97	88.5	92.5	90.5
	89	84	87	91	96	87.5	91.5	89.5
	87	83	85	89	94	86	89.5	87.75
2200	87	81	84	88	93	84.5	88.5	86.5
	85	80	83	87	91	83.5	87	85.25
	86	79	82	86	91	82.5	86.5	84.5
	86	79	82	87	90	83	86	84.5
	84	79	82	86	89	82.5	85.5	84
0000 2 Aug.	82	77	80	85	88	81	84	82.5
	81	74	78	84	86	79	82	80.5
	81	72	76	83	85	77.5	80.5	79
	81	72	77	83	85	77.5	81	79.25
	79	72	75	81	83	76.5	79	77.75
0200	79	72	75	80	83	76	79	77.5
	79	72	74	80	82	76	78	77
	78	72	74	79	82	75.5	78	76.75
	77	71	73	79	81	75	77	76
	75	70	72	78	80	74	76	75
0400	73	67	69	77	78	72	73.5	72.75
	72	66	69	75	77	70.5	73	71.75
	73	65	68	75	76	70	72	71
	69	64	67	73	75	68.5	71	69.75
	69	63	66	72	74	67.5	70	68.75
0600	68	63	66	71	73	67	69.5	68.25
	71	65	67	75	76	70	71.5	70.75
	77	74	71	80	79	77	75	76
	79	84	77	84	84	84	80.5	82.25

Time (Approximate) Aug. 2, 1972	Ambient (°F)	#1 (°F)	#8 (°F)	#10 (°F)	#12 (°F)	Avg.#1 & #10 (°F)	Avg.#8 & #12 (°F)	Avg. all 4 "Bulk"
	80	93	81	89	87	91	84	87.5
0800	83	101	85	92	91	96.5	88	92.25
	85	108	89	93	93	100.5	91	95.75
	86	114	93	96	97	105	95	100
	88	121	96	98	100	109.5	98	103.75
	89	126	98	98	101	112	99.5	105.75
1000	91	130	101	100	103	115	102	108.5
	94	137	106	102	106	119.5	106	112.75
	96	143	109	104	109	123.5	109	116.25
	100	146	113	106	111	126	112	119
	100	149	117	107	114	128	115.5	121.75
1200	101	151	121	108	117	129.5	119	124.25
	103	150	127	110	119	130	123	126.5
	104	156	129	110	121	133	125	129
	104	154	133	111	122	132.5	127.5	130
	105	155	137	112	125	133.5	131	132.25
1400	105	156	141	114	126	135	133.5	134.25
	107	149	143	114	127	131.5	135	133.25
	107	149	146	115	128	132	137	134.5
	106	151	152	118	131	134.5	141.5	138
	107	144	152	120	132	132	142	137
1600	108	139	152	119	131	129	141.5	135.25
	107	136	147	120	130	128	138.5	133.25
	107	136	147	121	130	128.5	138.5	133.5
	105	131	147	121	130	126	138.5	132.25
	103	124	144	120	128	122	136	129
1800	103	117	134	117	124	117	129	123
	100	111	119	113	121	112	120	116
	98	105	118	108	117	106.5	117.5	112
	95	99	103	103	109	101	106	103.5
	93	91	93	97	103	94	98	96
2000	91	87	90	94	100	90.5	95	92.75
	90	85	88	93	98	89	93	91
	88	83	86	91	96	87	91	89

Time (Approximate) Aug. 2, 1972	Ambient (°F)	#1 (°F)	#8 (°F)	#10 (°F)	#12 (°F)	Avg. #1 & #10 (°F)	Avg. #8 & #12 (°F)	Avg. all 4 "Bulk"
	87	81	85	90	94	85.5	89.5	87.5
	85	80	83	88	93	84	88	86
2200	84	78	81	87	91	82.5	86	84.25
	82	75	78	86	89	80.5	83.5	82
	85	74	79	85	88	79.5	83.5	81.5
	83	76	78	85	87	80.5	82.5	81.5
	81	74	77	84	86	79	81.5	80.25
0000 3 Aug.	78	71	75	83	84	77	79.5	78.25
	81	69	74	81	84	75	79	77
	79	70	73	81	83	75.5	78	76.75
	79	72	74	80	83	76	78.5	77.25
	78	71	73	79	82	75	77.5	76.25
0200	77	70	72	78	81	74	76.5	75.25
	73	69	71	77	79	73	75	74
	72	65	69	76	78	70.5	73.5	72
	70	64	68	74	77	69	72.5	70.75
	67	63	66	73	75	68	70.5	69.25
0400	67	61	65	71	74	66	69.5	67.75
	66	60	64	70	73	65	68.5	66.75
	65	60	63	70	72	65	67.5	66.25
	65	58	61	69	71	63.5	66	64.75
0600								
FIRST DAY'S TEMPERATURE RANGES								
HIGH	110	157	143	119	129	136	136	135.75
LOW	69	64	67	73	75	68.5	71	69.75
AVG	89.5	110.5	105	96	102	102.25	103.5	102.75
SECOND DAY'S TEMPERATURE RANGES								
HIGH	108	156	152	121	132	135	142	138
LOW	65	58	61	69	71	63.5	66	64.75
AVG	86.5	107	106.5	95	101.5	99.25	104	101.38

Series 2

Time (Approximate) Aug. 1, 1972	#3 (°F)	#2 (°F)	#9 (°F)	#11 (°F)	#13 (°F)	Avg.#2 & #11 (°F)	Avg.#9 & #13 (°F)	Avg. all 4 (°F)
0536	97	83	84	85	85	84	84.5	84.25
0600	96	82	83	85	84	83.5	83.5	83.5
0624	95	82	83	84	85	83	84	83.5
0648	94	85	84	86	89	85.5	86.5	86
0712	94	88	86	88	93	88	89.5	88.75
0736	93	91	88	90	96	90.5	92	91.25
0800	92	95	90	91	99	93	94.5	93.75
	91	98	92	93	102	95.5	97	96.25
	91	101	94	95	104	98	99	98.5
	91	105	96	97	107	101	101.5	101.25
	91	108	98	98	109	103	103.5	103.25
1000	91	112	101	100	112	106	106.5	106.25
	91	115	103	102	113	108.5	108	108.25
	92	118	105	103	115	110.5	110	110.25
	94	120	108	105	117	112.5	112.5	112.5
	94	122	110	106	118	114	114	114
1200	95	125	111	108	119	116.5	115	115.75
	96	126	114	109	120	117.5	117	117.25
	98	128	117	111	121	119.5	119	119.25
	100	130	119	112	122	121	120.5	120.75
	101	130	120	113	122	121.5	121	121.25
1400	102	131	122	114	122	122.5	122	122.25
	103	131	123	115	121	123	122	122.5
	105	131	124	117	121	124	122.5	123.25
	107	129	125	117	121	123	123	123
	108	129	125	118	120	123.5	122.5	123
1600	109	127	125	117	119	122	122	122
	111	126	125	117	119	121.5	122	121.75
	112	125	125	118	118	121.5	121.5	121.5
	113	124	125	118	117	121	121	121
	114	123	124	117	116	120	120	120

Time (Approximate) Aug. 1, 1972	#3 (°F)	#2 (°F)	#9 (°F)	#11 (°F)	#13 (°F)	Avg.#2 & #11 (°F)	Avg.#9 & #13 (°F)	Avg.all 4 (°F)
1800	115	121	123	117	115	119	119	119
	115	119	121	115	113	117	117	117
	116	117	119	114	112	115.5	115.5	115.5
	117	115	116	112	111	113.5	113.5	113.5
	117	111	111	109	108	110	109.5	109.75
2000	117	107	107	106	106	106.5	106.5	106.5
	117	105	105	104	104	104.5	104.5	104.5
	116	103	103	103	102	103	102.5	102.75
	116	101	101	101	101	101	101	101
	115	100	100	100	100	100	100	100
2200	114	98	98	98	98	98	98	98
	113	97	97	97	97	97	97	97
	112	95	95	96	95	95.5	95	95.25
	111	94	95	95	95	94.5	95	94.75
	110	93	94	94	94	93.5	94	93.75
0000 2 Aug.	109	92	93	93	93	92.5	93	92.75
	107	91	91	92	92	91.5	91.5	91.5
	106	89	90	91	90	90	90	90
	105	88	89	90	89	89	89	89
	104	87	88	89	89	88	88.5	88.25
0200	103	87	87	88	88	87.5	87.5	87.5
	102	86	86	87	87	86.5	86.5	86.5
	101	85	86	87	86	86	86	86
	100	84	85	86	85	85	85	85
	99	83	84	85	85	84	84.5	84.25
0400	97	82	83	84	83	83	83	83
	96	81	82	83	82	82	82	82
	95	80	80	82	81	81	80.5	80.25
	94	79	80	81	80	80	80	80
	93	78	79	80	79	79	79	79
0600	92	77	78	79	78	78	78	78
	91	76	77	79	80	77.5	78.5	78
	90	79	78	80	84	79.5	81	80.25
	89	82	80	82	88	82	84	83

Time (Approximate) Aug. 2, 1972	#3 (°F)	#2 (°F)	#9 (°F)	#11 (°F)	#13 (°F)	Avg. #2 & #11 (°F)	Avg. #9 & #13 (°F)	Avg. all 4 (°F)
	88	87	82	85	92	86	87	86.5
0800	87	90	85	87	96	88.5	90.5	89.5
	86	95	87	89	99	92	93	92.5
	86	98	90	91	102	94.5	96	95.25
	86	102	92	93	105	97.5	98.5	98
	86	106	95	95	107	100.5	101	100.75
1000	87	108	97	96	108	102	102.5	102.25
	87	111	99	98	110	104.5	104.5	104.5
	88	115	102	100	113	107.5	107.5	107.5
	89	118	104	101	114	109.5	109	109.25
	90	120	107	103	115	111.5	111	111.25
1200	91	122	109	105	116	113.5	112.5	113
	92	123	111	107	117	115	114	114.5
	94	125	114	108	117	116.5	115.5	116
	95	127	116	109	118	118	117	117.5
	97	127	118	110	118	118.5	118	118.25
1400	98	128	120	111	119	119.5	119.5	119.5
	100	128	121	112	118	120	119.5	119.75
	102	128	122	113	118	120.5	120	120.25
	103	129	125	115	118	122	121.5	121.75
	105	129	126	116	118	122.5	122	122.25
1600	106	128	127	116	118	122	122.5	122.25
	107	127	127	117	117	122	122	122
	109	126	127	118	117	122	122	122
	110	126	128	119	117	122.5	122.5	122.5
	111	124	127	118	116	121	121.5	121.25
1800	112	122	125	117	115	119.5	120	119.75
	114	120	123	117	113	118.5	118	118.25
	114	117	120	114	112	115.5	116	115.75
	115	114	116	112	110	113	113	113
	116	110	110	108	107	109	108.5	108.75
2000	116	107	107	106	105	106.5	106	106.25
	116	104	104	103	103	103.5	103.5	103.5
	115	102	102	102	101	102	101.5	101.75

Time (Approximate) Aug. 2, 1972	#3 (°F)	#2 (°F)	#9 (°F)	#11 (°F)	#13 (°F)	Avg.#2 & #11 (°F)	Avg.#9 & #13 (°F)	Avg.all 4 (°F)
	115	100	100	100	100	100	100	100
	114	98	99	99	98	98.5	98.5	98.5
2200	113	96	97	97	96	96.5	96.5	96.5
	112	95	95	96	95	95.5	95	95.25
	111	93	94	94	93	93.5	93.5	93.5
	110	92	93	93	93	92.5	93	92.75
	109	91	91	92	91	91.5	91	91.25
0000 3 Aug.	108	89	90	91	90	90	90	90
	106	88	89	90	89	89	89	89
	105	87	88	89	88	88	88	88
	104	86	87	88	87	87	87	87
	103	85	86	87	87	86	86.5	86.25
0200	101	85	85	86	86	85.5	85.5	85.5
	100	84	84	85	85	84.5	84.5	84.5
	99	82	83	84	83	83	83	83
	98	81	82	83	82	82	82	82
	97	80	80	81	81	80.5	80.5	80.5
0400	95	78	79	80	79	79	79	79
0424	94	77	78	79	78	78	78	78
0448	93	76	77	78	77	77	77	77
0512	92	75	76	77	76	76	76	76
			FIRST DAY'S TEMPERATURE RANGES					
HIGH	117	131	125	118	122	124	123	123.25
LOW	91	79	80	81	80	80	80	80
AVG	104	105	102.5	99.5	101	102	101.5	101.63
			SECOND DAY'S TEMPERATURE RANGES					
HIGH	116	129	128	119	119	122.5	122.5	122.5
LOW	86	75	76	77	76	76	76	76
AVG	101	102	102	98	97.5	99.25	99.25	99.25

APPENDIX E

Uncertainty Analysis

An uncertainty analysis was carried out on both the analytical solution and on a one dimensional TRUMP model of the rocket motor storage container system. In both models, the volumetric heat capacity of the sand (ρc), the conductivity of the sand (k), and the emissivity of the surfaces were each varied by ten percent to determine the sensitivity of the system temperature response to each variation. Although other factors may also be varied, it was theorized that these three had the greatest effect on the heat transfer of the system. These factors were also known with the least accuracy; the maximum uncertainty of each was estimated to be plus or minus ten percent (odds 20 to 1).

In the analytical solution, varying the volumetric heat capacity changed parameter a, varying the emissivity changed parameter β, and varying the conductivity changed both parameters a and β. The effects on each parameter from each variation are given in Table V.

TABLE V
Change in Parameters due to Changes in Thermal Properties

Change in Property	Change in Parameters
Volumetric Heat Capacity + 10%	a + .12
Volumetric Heat Capacity - 10%	a - .12
Emissivity + 10%	β + .49
Emissivity - 10%	β - .37
Conductivity + 10%	a - .11, β - .22
Conductivity - 10%	a + .13, β + .35

Each factor was varied holding the other factors constant. The changes in temperature and time delay were computed from the difference between these new values and those previously obtained from the analytical solution. To obtain uncertainty bounds on the analytical curve, the second power equation [Ref. 16] was used, namely

$$\omega_T = \sqrt{\omega_C^2 + \omega_k^2 + \omega_\varepsilon^2}$$

where

ω_T = resulting uncertainty in the calculated temperature due to uncertainties in temperature caused by

ω_C = estimated uncertainty in volumetric heat capacity
ω_k = estimated uncertainty in conductivity
ω_ε = estimated uncertainty in emissivity

An identical calculation was carried out to calculate the uncertainty in time delay. The results of these calculations are shown in Figures 12 and 13 for the surface and center of the rocket motor respectively. The uncertainty in temperature varied with time with a maximum variation of ±2.75°F at the center of the motor and a maximum variation of ±1.85°F at the surface of the rocket motor. The time delay varied by ±31 minutes at the center of the motor and ±11 minutes at the surface. The actual experimental data was also plotted on these Figures for comparison.

The experimental data also had an uncertainty bound. Three primary factors made up this uncertainty bound; the accuracy of the thermocouple wire (±1.5°F), the readability of the recorder (±1°F), and the variation in temperature

caused by inaccuracy in the placement of the thermocouples (±1°F, estimated). The overall uncertainty in the experimental data was also calculated from the second power equation as

$$\omega_T = \sqrt{\omega^2_{WIRE} + \omega^2_{READ} + \omega^2_{PLACE}} \approx 2°F$$

These uncertainty bounds are also shown in Figures 12 and 13.

A procedure, similar to that used to find the uncertainties of the analytical solution, was used to analyze the resulting uncertainty in the TRUMP numerical calculation. The results of these calculations are shown in Figures 14 and 15. The uncertainty in temperature varied with time with a maximum variation of ±2.95°F at the center of the rocket motor and a maximum variation of ±1.95°F at the surface of the motor. The time delay varied from ±20 minutes at the center of the motor to ±9 minutes at the surface of the motor.

On the basis of the propagation of uncertainty analysis, it was determined that the solutions were most sensitive, in order of importance, to changes in the volumetric heat capacity, emissivity, and the conductivity.

LIST OF REFERENCES

1. Arpaci, V. S., Conduction Heat Transfer, p. 324-328, Addison-Wesley, 1966.

2. Lawrence Radiation Laboratory Report No. UCRL-14754, Rev. II, TRUMP: A Computer Program for Transient and Steady-State Temperature Distributions in Multidimensional Systems, by A. L. Edwards, 1 July 1969.

3. Erbayrum, C., A Computer Program for Solving Transient Heat Conduction Problems, M.S. Thesis, Naval Postgraduate School, Monterey, California, 1971.

4. Meyer, J. F., MacKenzie, D. K., and Wirzburger, A. H., Thermal Mapping of Surface Temperatures Using Cholesteric Liquid Crystals, laboratory study done at Naval Postgraduate School, Monterey, California, 9 June 1972.

5. Crawford, L. and Lemlich, R., "Natural Convection in Horizontal Concentric Cylindrical Annuli," Industrial and Engineering Chemistry Fundamentals, Vol. 1, No. 4, p. 260-264, November 1962.

6. Baumeister, T., Marks Standard Handbook for Mechanical Engineers, 7th Edition, p. 4-11, 4-95, 4-111, McGraw-Hill, 1967.

7. Liu, C. Y., Mueller, W. K., and Landis, F., Natural Convection Heat Transfer in Long Horizontal Cylindrical Annuli, paper presented at 1961 International Heat Transfer Conference, Boulder, Colorado, 28 August - 1 September 1961.

8. Fergason, J. L., Taylor, T. R., and Harsch, T. B., "Liquid Crystals and their Applications," Electro-Technology, p. 41-50, January 1970.

9. Fergason, J. L., "Liquid Crystals," Scientific American, V. 211, p. 77-85, August 1964.

10. Naval Air Development Center Report No. NADC-MA-6922, Development of a Reusable Strippable Film as a Carrier for Liquid Crystals for Use in NDT, by E. Th. Vadala, p. 1-3, 22 May 1969.

11. Hoehn, R. and Binkert, B., Cholesteric Liquid Crystals: A New Visual Aid to Study Flap Circulation, paper presented at Annual Meeting of the American Society of Plastic and Reconstructive Surgeons, Los Angeles, California, 5 October 1970.

12. Mock, J. A., "Liquid Crystals Track Flaws in a Colorful Way," *Materials Engineering*, p. 66-67, February 1969.

13. McLachlan, N. W., *Bessel Functions for Engineers*, 2nd Ed., p. 135-136, Oxford University Press, 1961.

14. Hottel, H. C., and Sarofim, A. F., *Radiative Transfer*, p. 31-39, McGraw-Hill, 1967.

15. Chapman, A. J., *Heat Transfer*, 2nd Ed., p. 450-455, Macmillan Co., 1967.

16. Kline, S. J., and McClintock, F. A., "Describing Uncertainties in Single-Sample Experiments," *Mechanical Engineering*, p. 3-8, January 1953.

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RACT

The heat transfer characteristics of a rocket motor storage con-
er system have been investigated using analytical and experimental
niques. Analytically, both closed form and numerical solutions
been developed. These solutions may be used to determine maximum
eratures and temperature gradients within the rocket motor. Com-
son between theoretical and experimental values of temperature are
in the estimated experimental uncertainties of ± 3°F. It is pro-
d that the theoretical solutions can be used to thermally optimize
ainer design.

A secondary investigation was carried out to determine the feasi-
ty of using cholesteric liquid crystals, a temperature sensitive
rial, to thermally map the surface of the container. The crystals
ar to remain stable under desert type conditions and produce
liantly colored displays of the temperature field.

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